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The Automatic Control of Machine Tools

By F. W. CUNNINGHAM. (From *Mechanical Engineering, U.S.A.*, Vol. 76, No. 6, June 1954, pp. 487-490.)

MACHINE tools have been controlled automatically and satisfactorily for a great many years. The automatic screw machine is familiar to all engineers. Another widely used type of machine is the copying or tracer-controlled machine. On these machines a first piece or template is made by conventional methods, and then a cutting tool is guided automatically so as to duplicate the form in the workpiece. In some cases a master is made of wood and plaster, which can then be cut in metal. All these machines have the disadvantage of requiring that a master piece or, in the automatic screw machine, a set of master cams, be made and installed every time the machine is to be changed from one job to another.

When a single piece is required, the simplest method is probably to hand a rough sketch to a good mechanic and let him make it. If 10,000 or 50,000 pieces are to be made, the machines mentioned are available. If, however, the number to be made is 6, 10, or 25, there would appear to be no good ways of making them. If they are given to a good mechanic, he makes the second piece a little faster than the first, but the third takes just as long as the second, and he can easily spoil the fifth. He has to stop his machine repeatedly to change tools and measure the work. He rarely takes as heavy a cut as the job will stand, as he is afraid of spoiling it.

During the past 150 years or so, these considerations have led to the development of machines which can be controlled by a tape or film. In about 1804 J. M. Jacquard invented a loom which was controlled by punched cards linked together in a chain. This control device has been applied to embroidery machines and to lace-making machines. A related system has been used widely for player pianos and organs, and a similar method for the control of typesetting machines.

With a tape system, when new orders come in for spare parts, it is necessary only to take the tape out of the file and put it in the machine, and to put in a piece of stock. In fact, the operator does not even need to know what the machine is going to make, but merely to know what size stock to put in and where to put it.

For exceptionally complicated pieces, it is possible to prepare tapes on some of the large modern computing machines. For simple pieces, however, it should be possible to prepare a tape in the user's plant. If the information can be put on teletype tape, the possibility appears of telegraphing spare parts all over the world.

In the machine-tool field, the problems are somewhat different from those on the earlier devices, most of which employ a hole in the tape for each particular operation or location. On a machine tool, however, it may be desired to locate a point to 0·0001 in. or 0·0002 in. on a machine having a total travel of 50 or 60 in., representing one part in 500,000 or 600,000. Obviously, it is impossible to have a tape 500,000 holes wide, and have each put up a locating pin 0·001 in. from the next one.

There are several ways of avoiding this problem. One is to use a coding system of some kind. The simplest system is merely the use of decimal dimensions; in other words, if the cutter is to be 19·5732 in. from the zero point, the digits 195732 are punched in the tape. This will require 60 spaces to be available for this co-ordinate. A binary system would permit a reduction to 19 spaces, while a combination system using 4 spaces per decade would require 24.

The number of spaces can be reduced greatly if it is not necessary to give a single order that will drive the machine from end to end. The simplest type of control system is one in which successive equal steps are transmitted to the tool. As frequently as the system will allow, a step is either fed in, or it is omitted. Such a system requires a reliable response device. It also requires a greater length of tape than a control which uses a code to indicate the final co-ordinate of the tool. If the steps are 0 0001 in., and the signals on the tape are $\frac{1}{8}$ in. apart, a tape over a mile long would be required to make a single 60-in. cut. At a cutting speed of 1 in. per sec, the speed of the tape would be over a mile a minute. A magnetic tape will permit much closer spacing of orders than $\frac{1}{8}$ in., but it is somewhat difficult to make changes on such a tape.

SYSTEM FLEXIBILITY

A matter of great importance to the engineer concerned with automatic control is a knowledge of the degree of flexibility desirable in a system. If great flexibility is required, additional complexity may result. Cost is the final controlling element. If a machine will not do a job less economically, than it can be done some other way, it is not a practical machine-tool control.

The degree of flexibility required depends to some extent on the machine to which the control is to be applied. On a jig-boring machine, for instance, the important feature of the control is that it shall locate the workpiece accurately and quickly. A slight lack of uniformity in the velocity of approach is not important, nor is control of that velocity over a wide range. In a lathe, the degree of flexibility required may be important. A simple type of control can be built to do straight turning. To turn accurate tapers may add appreciably to the cost of the control system, while to be able to cut irregular forms may add to it very considerably. This will be true if the number of orders to be given the machine is to be kept low. If a large number of orders is to be given, as in a step-by-step system, the same control will work on one as on the other, but the labour of preparing the control tape may be increased.

A machine which will do straight turning will do anything, if it is done in straight steps of sufficiently small size, but this results in poor speed of operation. It may result in such poor speed that difficulties will be encountered when cutting material such as stainless steel, where it is necessary to take a sufficiently heavy cut each time to get below the work-hardened surface from the revolution before. The cost of the control also will be influenced by the number of dimensions. Pieces, of course, exist in three dimensions, but the speed of operation may result in a fourth dimension.

PLAYBACK CONTROLS

One type of control which has received much attention in the past is the playback machine. A machinist operates a machine tool in a normal manner, the motions of the machine being recorded in some

way on tape or film, magnetic tape, or motion-picture film, or anything else. Then, when the machine is played back, the motions are repeated. One of the disadvantages is that, if the machinist makes unnecessary motions, those motions are repeated. It is also probably true that a machinist rarely operates a machine tool at maximum possible cutting rates. Especially after the first few operations, he does not wish to spoil the piece, and takes extra unnecessary cuts or less speed than the machine is capable of tolerating. In consequence, his faults are repeated every time he makes another piece.

In this connection, it is understood that M. Faure in France is working on a machine on which the record is not made until the operation is complete. Thus, an operator can take a cut and can decide whether it is the cut required ; if it is, he can then record it merely by pushing a button. If, however, he decides that it is not satisfactory, he can repeat the operation with a suitable correction before recording it permanently.

Safety Precautions

It is important that the equipment be reliable. Some safety precautions certainly need to be taken. To make equipment completely foolproof is probably impossible. To be completely, or as nearly, foolproof as possible would perhaps involve a complete duplicate system with two tapes—a transmitting tape which would transmit to the machine tool what it was supposed to do, and a checking tape which would receive information from the machine tool or from the workpiece, perhaps from a diamond leaning against the work, or from a point as near as possible to the work. This would transmit from the machine back to the checking tape prepared independently, in which case any discrepancy between the order and the response would result in stopping the machine or ringing an alarm, or whatever is necessary.

Anything which may result in damage to the machine tool itself is probably very serious. If it damages an ordinary lathe tool, it is not too important. If it damages the workpiece, it may or may not be very important, depending on the value of the workpiece. It is important that the machine-tool control be easily serviced. That, naturally, is of less importance as the reliability of the machine goes up. A machine which is likely to break down requires easy servicing ; a machine which is unlikely to fail can tolerate some difficulty.

Electronic Equipment

An important reason why automatic controls were not applied to machine tools many years ago was the lack of sufficient experience with servo-mechanisms, vacuum tubes, etc. To-day, vacuum-tube servos and thyratron servo-mechanisms are both reliable, and most failures in these systems have been mechanical. Loose connections, for instance, are as likely a cause of trouble as anything else, though, of course, vacuum tubes do fail, sometimes gradually, sometimes all at once.

Work is currently being done with transistors, which it is hoped will be better than tubes. Magnetic amplifiers will certainly be used in future for the somewhat higher power levels, the driving servo-motors. There are also friction drives, such as mechanical-torque amplifiers, using metal bands wrapped around drums. For low powers, a straight synchro-transmission has been used.

The power requirements for machine-tool control may turn out to be surprisingly large. Lathes, for example, may require, under the worst conditions, 3 or 4% of the power required to drive the spindle. This takes such servo-mechanisms out of the instrument class used in computers, etc., which ordinarily have maximum outputs of a few watts, and raises them into the power-drive class.

Tape-Control Machines Constructed

Several tape-control machine tools have been constructed or described within the past few years. In one simple system, no attempt is made to operate the machine tool at its maximum capacity. Its function primarily is to machine parts so intricate as to be extremely difficult to machine by ordinary methods. The equipment uses a tape about 4½ in. in width, and handles 4 co-ordinates, with 16 possible values for each of the co-ordinates. There are 4 tracks in the tape for each co-ordinate. The combinations of the four of them give 16 possibilities. For every step, 4 holes are punched. They may be in one of two different rows, and there will always be a hole in one row or the other. A small rocker mechanism is brought toward the tape, and rocks one way or the other, depending on which hole is punched. As it moves farther, it encounters a dog which forces the rocker farther in the direction in which it is moving. It then closes electrical circuits which operate relays, to provide any one of 16 different sets of voltages which are fed directly to a synchro-motor. This motor simply drives the proper carriage of the machine tool. The steps are each 22½ deg. of synchro-rotation, corresponding to a motion of 0·001 in.

If the steps were much smaller, it would be necessary to use servo-mechanisms to aid the synchroniser in driving the load. There is no provision, at present, for backlash compensation. If the amount of backlash is known, it can be allowed for, or if turning is done from the outside, it is always in the same direction.

If the tool wears, some adjustment must be made. If, for some reason, the machine fails to respond to one step, the next step will correct it anyway, by moving the synchroniser by 45 deg. For that matter, double or triple steps can be put in, if desired, to increase the speed of operation. As long as eight or more are not present at one time, the machine will drive in the right direction. It is probably not advisable to put in more than three, in practice. Considering speeds and accelerations, it might happen that the lags of the system would be such that, if two steps of five were put in from a standstill, the resultant rotation would be in the wrong direction.

Another system is considerably more elaborate. This is a numerically controlled milling machine in which the operation in each co-ordinate is in essentially a straight line, although it actually is divided up into small steps each way. However, it is necessary only to put in, in coded form, the length of travel which a cut is to have, and the time necessary to complete that cut. The minimum time that can be used is 2 sec.

The machine operates by taking steps at a fixed rate of 512 per second, and then taking as many of those steps as are necessary. If the machine is to travel at full speed, in a second it will take all but one of them. If it is to travel at half that speed, it will take every odd step ; at a quarter of that speed, it will take the second, sixth, tenth, and so on. Intermediate speeds are taken by adding groups of steps. At ¾ speed, the steps used for ½ speed are taken with those for ¼ speed. There is a rather ingenious system for effecting this, based on the properties of binary counting systems, and the use of the pulse which does not carry to the next one.

The steps on this milling machine have been 0·0005 in., giving a maximum cutting speed of 15 ipm. This is a reasonable speed, but it is nowhere near the highest useful speed of the milling machine to which it is applied. It is understood that in cutting aluminium, it is not unusual to operate these machines at the rapid traverse speed of 120 ipm. On a lathe, it is felt that something around 60 ipm for the longitudinal speed, and perhaps a little less for the cross feed, would be suitable maximum speed rates.

A few years ago, a lathe was built on which the information was fed in, in the form of the co-ordinates

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Investigations into the Metal-Spraying Process

By A. MATTING and K. BECKER. (From *Schweissen und Schneiden*, Vol. 6, No. 4, April 1954, pp. 127-142, 40 illustrations.)

The Industrial Materials Research Institute of Hanover Technical University has for years engaged in research in connection with metal spraying. This article is a summary of the latest results of such research, and deals with the processes taking place in the spray nozzle.

IN the process of metal spraying, four distinct stages can be recognised, changes in any one of which must naturally affect the composition and structure, and hence also the properties, of the sprayed layer. These stages are as follows :—

(1) *Heating of the spraying medium to melting point:*—If acetylene is used as the fuel gas, combustion takes place in three zones, i.e., the breakdown zone of the acetylene into carbon and hydrogen in the interior of the luminous flame cone ; the partial-combustion zone of the carbon into carbon monoxide on the fringe of the luminous flame cone ; and the combustion zone of carbon monoxide into carbon dioxide, and hydrogen into water vapour, in the bluish, secondary luminous flame. It may be assumed that there are no fundamental differences between the spray-gun flame and the standard welding flame. In contrast to gas welding, however, the spray wire comes into contact with all three zones, because it is fed axially through the flame. It is presumably of special importance in this connection that the highly heated wire surface may be acted upon by free oxygen and carbon within the flame cone.

(2) *Atomisation and acceleration of the molten material:*—The molten metal is forced off the wire tip by the high-velocity flame gases, which are further accelerated by means of compressed air.

(3) *Processes accompanying motion in the spray jet:*—It is fairly certain that, at the moment of their formation, spray particles are in a molten state ; consequently, in the case of pure metals with a definite melting point, their temperature approximates this point, whilst, in the case of alloys, the particle temperature lies between the solidus and the liquidus, viscosity probably being of some importance. It is equally certain that, when steel is sprayed, reactions which alter the particle temperature take place between the highly heated surfaces of such particles and the ambient gas atmosphere. It is also possible that such reactions affect the shape of the particles, which, because of surface tension, should presumably be spherical.

It can be stated that the particle temperature in the jet is determined by : (1) The temperature of the ambient gas ; (2) the relative velocity between particles and gas atmosphere ; (3) the heat transfer between gas and particles ; and (4) the heat of reactions, if any, liberated.

(4) *Impact of particles and layer formation:*—The theory of some investigators that the particles lose considerable heat before striking the workpiece, but weld with it and with each other through the conversion of their kinetic energy into heat at the moment of impact, has been disproved. It was later believed that layer formation was purely a process of mechanical interlocking. This hypothesis, in turn, is contradicted by several properties of the layers. Some investigators advance the seemingly improbable theory that the particles can fuse with the workpiece and with each other only by a process of " cold welding " but, as will be shown later, there is much to be said for this belief.

Evaluation of the various investigations on layer formation indicates the following correlations :—

(1) Adhesion increases with an increase in workpiece temperature.
(2) The bending angle at which the layer will crack increases with increasing workpiece temperature during manufacture.
(3) Adhesion diminishes with an increase in spraying distance.
(4) The tensile strength of the layer increases with a decrease in its oxide content.
(5) Adhesion, in the case of zinc, increases with increasing air pressure.
(6) Adhesion, in the case of steel, increases with a reducing gas atmosphere, accompanied by increasing air pressure.
(7) Adhesion, in the case of steel, diminishes in a neutral atmosphere, with increasing air pressure.
(8) The electrical conductivity of sprayed layers is normally about 90% of that of rolled materials ; in the case of aluminium, however, it is only 20%.

PURPOSE OF THE INVESTIGATION

The main problems requiring solution would appear to be the following :—

(a) *Processes taking place at the wire tip:*—It is desirable not only to ascertain the exact temperatures of the wire tip, but also to make particle formation visible.

(b) *Motion of the particles in the spray jet:*—Information on a particle acceleration and impact velocity would be of special interest.

(c) *Formation of oxide films:*—Oxide-free spray layers constitute a prime condition for the employment of such layers as a protection against corrosion in chemical apparatus and containers. It is therefore of extreme importance to obtain data on oxide formation, with a view to its restriction.

Interpretation of the results obtained from an investigation of these problems should be of considerable value in helping to decide which of the three above-mentioned theories on the formation of sprayed layers is the most probable.

METAL-SPRAYING APPARATUS

All experiments were carried out with a modern spray gun, in which the wire was fed, *via* a flexible drive, from an infinitely variable speed gear, mounted outside the gun casing. Only commercial bottled acetylene and oxygen were used. Compressed air was taken at 5 atm gauge pressure *via* two oil filters arranged in series, while two pressure-reducing valves in series served to compensate any pressure fluctuations. Means of measuring oxygen, acetylene, and compressed-air quantities were provided. The pressure of the acetylene-

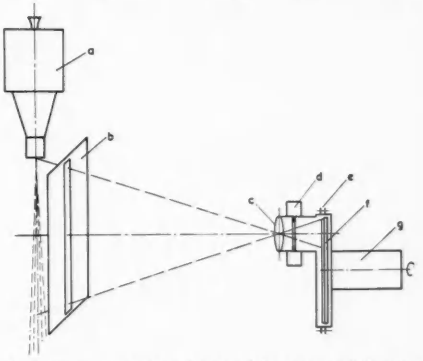


Fig. 1. **Test arrangement for special camera with rotating film.**
(a) Spray gun ; (b) slit ; (c) lens ; (d) shutter ; (e) casing ; (f) rotating film carrier ; (g) electric motor.

oxygen mixture between injector and nozzle, and that of the compressed air immediately before its entry into the gun, were also measured. Wire-feed rate was determined by means of a small d.c. generator connected to the wire-feed control gear.

Photographic Apparatus

Photomicrographic apparatus was used which was capable of providing exposures of between 10^{-6} and 10^{-7} sec, with clear enlargements up to $\times 30$.

Continuous observation of the processes at the wire tip was achieved with the aid of 16-mm motion-picture cameras taking 24, 64, 1500, and 3000 frames per second, and perfect photographs of these processes, as well as of the gas flow in the spray jet, were obtained.

To determine the exact propagation velocity of the particles in the spray jet, a special camera, embodying a rotating film, as shown in Fig. 1, was constructed. The light-sensitive film rotates at a known speed. The spray gun must be so positioned that the spray jet is exactly radial with respect to the rotating film. In all cases, object to image ratio was 6:1. Exposure times of the shutter were so chosen as to expose 75% of the film at all speeds. Owing to the superposition of the rotary motion of the film and the linear motion of the spray particles, a spiral trace is recorded on the film. From the curve thus obtained, the radial velocity component, i.e., the particle velocity, can be calculated, as the tangential velocity component, based on the predetermined speed of the film, is known.

Micro-Temperature Measurements

For this purpose, a micro-pyrometer was used, with correction factors for the micro-ammeter readings, the factor 0·40 being taken for the emissive capacity of steel and 0·88 for that of iron oxide(FeO). These correction factors are necessary, as the micro-pyrometer was calibrated for black-body radiations.

Experimental Results

Processes at the Wire Tip:—

In acetylene oxygen flames, the combustion process can be influenced very considerably by the choice of mixture ratio, while the amount of heat required to melt the wire is influenced by both the fuel-gas consumption per unit of time and the flame adjustment, as determined by the mixture ratio. Fig. 2 shows the experimentally ascertained heat requirement [kcal/gr] for steel wire, as ordinates in a three-dimensional co-ordinate system, whose abscissae present the relevant fuel-gas consumption and the mixture ratio $O_2/C_2H_2 = M$. To obtain comparable values, the wire feed was so adjusted that the tip always melted at the same level. The measured values lie, with only a little scatter, on a plane which declines at higher mixture ratios. In other words, less heat is required for melting as the proportion of oxygen increases. This accords with the fact that steel spraying can be carried out with oxygen and compressed air alone, once the process has been started, though the layer will then consist almost entirely of iron oxide.

The decrease in heat consumption with an increase in the mixture ratio M therefore suggests that a heat-liberating chemical reaction is taking place on the melting wire surface, even at mixture ratios of less than unity. This can consist only of the combustion of iron into iron oxide.

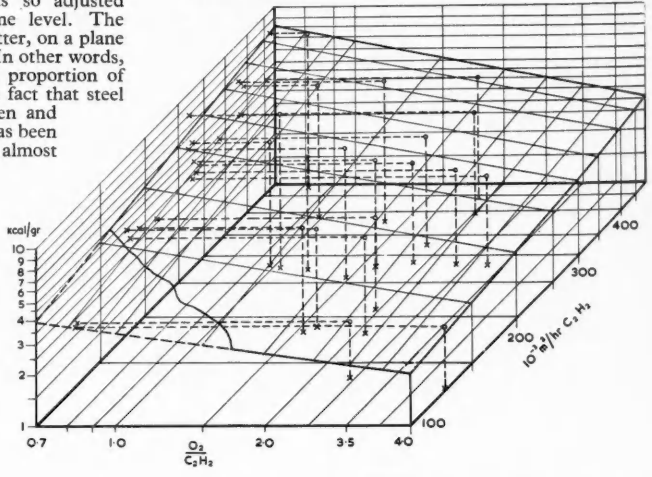


Fig. 2. **Melting diagram. Wire, 0·86% C-steel; air quantity, 13 m³/hr approximately.**

Fig. 3. **Oxide formation on molten wire surface.**

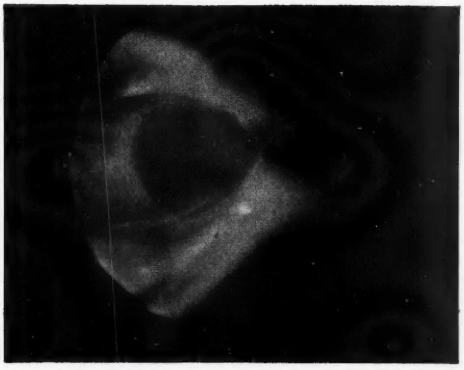


Fig. 4. **Oxide formation on molten wire surface.**

Oxide formation on the conical envelope of the melting wire tip is shown in Figs. 3 and 4, the bright iron-oxide islands standing out against the dark background. Fig. 5 shows that iron oxide has already formed within the region of the breakdown zone, i.e., within the cone of the flame. It is possible to discern the liquid oxide emerging from the interior of the air nipple, and being carried away by flame gases before reaching the wire tip. This oxide formation is possible because conductivity imparts a high temperature to those portions of the wire

Fig. 5. **Formation of oxide within the region of the breakdown zone.**

which have not yet reached the melting zone, and because free oxygen is always present in the breakdown zone.

It can also happen, as shown in Fig. 6, that, owing to an oxygen/steel reaction, the entire wire tip is detached and carried away by the flame gases in the form of a relatively large sphere with, however, relatively low acceleration. The liquid iron oxide formed at the point

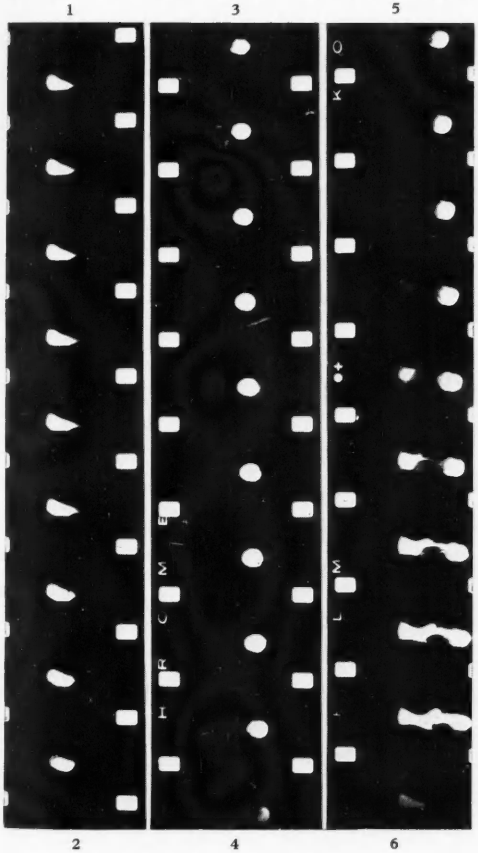


Fig. 6. **Section of film of combustion of wire tip.**
64 frames per second ; sequence, 1-2-3-4-5-6.

of detachment is taken up by the flame current and strikes the rear of the sphere, with which it travels together in the spray jet.

The combustion of the acetylene takes place in two stages, according to the following equations :—

(1) $2C_2H_2 + 2O_2 = 4CO + 2H_2$, with $M = 1$

(2) $4CO + 2H_2 + 3O_2 = 4CO_2 + 2H_2O$

Total result : $2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O$, with $M = 2{\cdot}5$.

A normal welding flame derives its oxygen for the second combustion stage from the ambient air. In spray guns, the flame cone is largely surrounded by the air nipple, so that here, too, the oxygen for the second stage can be provided by increasing the mixture ratio to more than unity. Thus, the combustion zone, which, with an excess of fuel gas, lies entirely outside the air nipple, can be drawn towards the interior of the nipple, thereby intensifying heat transmission from the flame to the wire tip. In addition, however, an increasing mixture ratio makes increasing amounts of free oxygen available, so that a steadily increasing portion of the heat requirement is covered by the combustion of the iron into iron oxide. This effect is particularly pronounced when M is greater than 2·5, because more oxygen is then supplied than is required for the complete combustion of the acetylene. Films of this investigation show that, when this mixture ratio is exceeded, the wire tip is automatically and completely covered by an iron-oxide layer.

When M is greater than 2·5, pyrometric temperature measurements showed at the wire tip a sudden drop in temperature from 1495° C to 1420° C. This drop again characterises the spontaneous oxide-film formation when this mixture ratio is attained. Collation with phase diagrams for iron/carbon and iron/oxygen shows that the measured temperature corresponds below $M = 2{\cdot}5$ with the solidus temperature of the particular steel employed. In an iron/oxygen diagram, the low temperature noted (about 1420° C), with $M = 2{\cdot}5$, would correspond to somewhat less than 22% of oxygen. However, the pure iron oxide, with 23·5% oxygen, has a lower melting point, i.e., 1360° C. The oxide is therefore considerably overheated and is highly fluid. It is immediately carried off by the flame jet, so that new oxide can be formed continuously and, at the same time, new heat for maintaining this process is produced, as in flame cutting.

Particle Formation:—

Valuable data on the process of particle formation were obtained with the aid of the photographic apparatus already described, 0·86% C-steel and electrolytic copper being investigated.

Fig. 7. **Feeding of metal into flame-gas stream.**
Material, 0·86% C-steel ; × 11.

Metal heated above the solidus gathers at the wire tip and adheres there until its surface tension is no longer adequate to resist the flame-gas stream (Fig. 7). The relatively viscous metal is first drawn into a thin thread (Figs. 8 and 9) ; it then contracts (Fig. 10) and finally breaks (Fig. 11), when it is atomised into flying particles (Figs. 12 and 13). If the flame is neutral, the flame gases within the atomisation range probably consist of carbon monoxide and molecular hydrogen, so that no notable chemical reactions between the particles

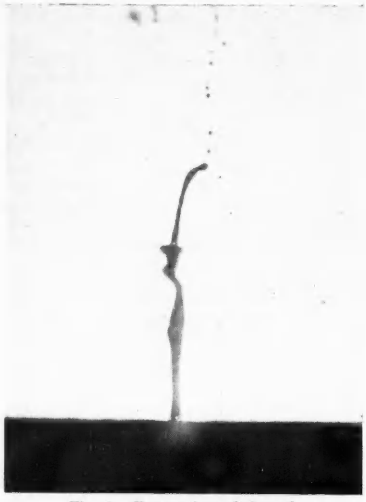


Fig. 8. **Formation of thread.**
Material, 0·86% C-steel ; × 11.

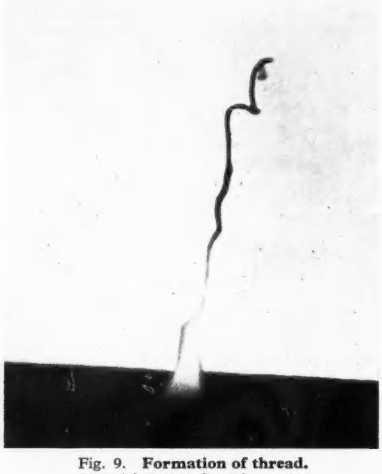


Fig. 9. **Formation of thread.**
Material, 0·86% C-steel ; × 11.

and the gas atmosphere are to be expected. When a portion of thread has been atomised, surface tension causes it to contract and to form a more or less blunt wire tip. The process is then repeated.

The mixture ratio *M* was found to affect the duration of the atomisation period. Thus, for example, spasmodic spraying was observed when the flame had a low oxygen content (Fig. 14), while steady spraying occurred when the flame had a high oxygen content (Fig. 15). The explanation of this phenomenon is that, in the presence of an excess of gas, the molten steel wire tip is carburised and its melting point is thereby reduced. As a result, the viscosity of the molten material is further reduced. The renewed increase in the frequency of the atomisation process at higher mixture ratios is due to a more intensive iron-oxide formation, and at very high ratios practically iron oxide only is sprayed off. This is detached with perfect continuity, as it possesses no solidification range.

Spasmodic spraying was also not observed in other substances with fixed melting points, such as pure metals.

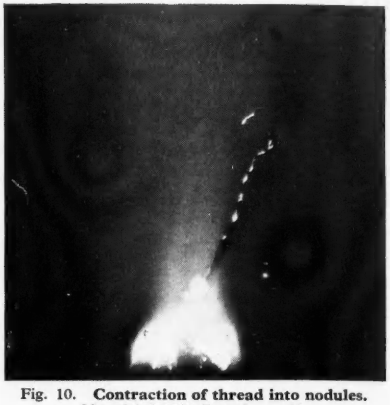


Fig. 10. **Contraction of thread into nodules.**
Material, 0·86% C-steel ; × 11.

Fig. 11. **Breaking of thread.**
Material, 0·86% C-steel ; × 11.

In the case of copper, a steadily thinning thread is formed, the end of which is evenly atomised.

Acceleration of Particles:—

Examination of the make-up of the gas stream in the spray jet, by means of a series of Schlieren photographs, revealed a low-density jet core immediately at the nozzle mouth, formed by the combustion gases, and, concentrically therewith, an envelope of higher density consisting of a mixture of combustion gases and compressed air. Furthermore, in the spray jet, a highly turbulent zone of compressed air and flame gases was discernible. The photographs also showed that the surrounding air is drawn into the spray jet. These processes are shown schematically, in Fig. 16. It was found that the size and shape of the jet core could be influenced by adjusting the gases and the nozzle shape.

Evaluation of the rotating films, which show the velocity diagram of the particles in polar co-ordinates, affords an accurate insight into the kinetic processes in the spray jet. It was noted that the particles are accelerated in a zone of from about 5 mm to 30 mm (measured from the wire tip). At 5 mm, the particles emerge and are seized by the gas stream. It is here, then, that the

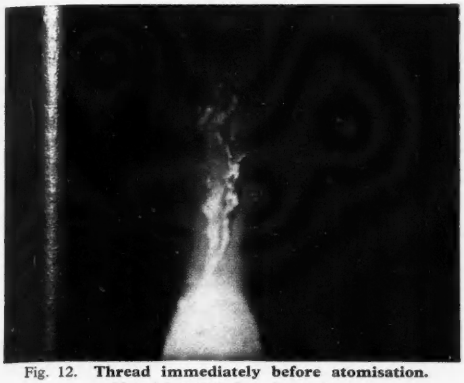


Fig. 12. **Thread immediately before atomisation.**
Material, 0·86% C-steel ; × 11.

highest relative velocity prevails between the gas atmosphere and the highly heated molten metal particles. Figure 17 shows that in this range individual particles suddenly light up. This can be due only to combustion of the particles in the gas atmosphere, if it contains free oxygen. Whether such combustion takes place on the surface only or is complete is determined by the proportion of free oxygen and by the velocity difference between the gas stream and the particles. If the acceleration zone can be made to coincide with the jet core shown in Fig. 16, where the atmosphere is neutral, it must be possible to prevent oxidation entirely.

The particles in flight within the spray jet, from the nozzle mouth to the workpiece, record a uniformly illuminated track on the photographs, as shown in Fig. 18, and no notable oxidation is therefore to be assumed.

In contrast, the particles which, once accelerated, reach the fringe of the jet, indicate by a sudden glow that a reaction with oxygen has taken place (Fig. 19). As these, after lighting up, do not darken the film, it must be assumed that they immediately cool down in this portion of the spray jet, owing to the lower temperature of the gases.

Motion-picture films at 1500 frames per second show near the workpiece an annular zone in which a number of particles suddenly lights up. These are probably particles whose kinetic energy is too low for combination with the workpiece or the already existing layer. As a result, they rebound into the atmosphere and, as their relative velocity and temperature are still high, they ignite spontaneously. On the other hand, any notable oxidation of those particles which contribute to the layer of sprayed metal at the moment of impact is improbable.

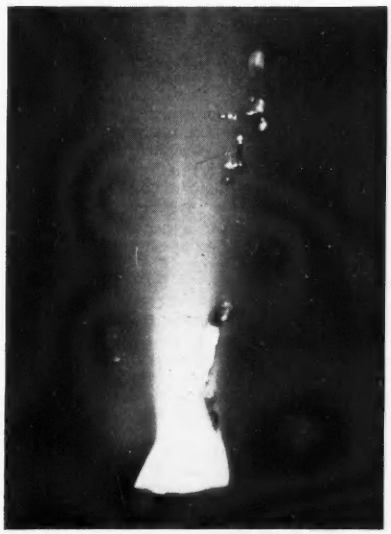


Fig. 13. **Particles in flight.**
Material, 0·86% C-steel ; × 11.

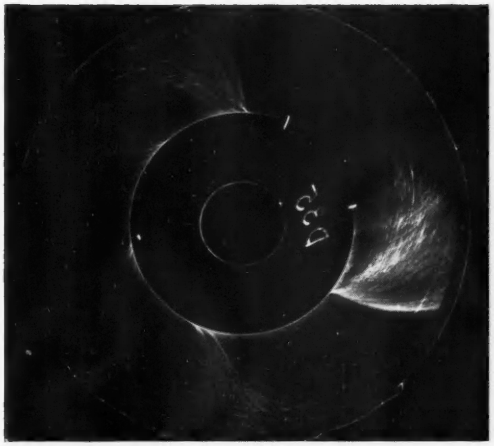


Fig. 14. **Rotating film exposure, showing spasmodic spraying with reduced oxygen content of flame.**
M = 1·88 ; speed, 3200 rpm ; material, 0·86% C-steel.

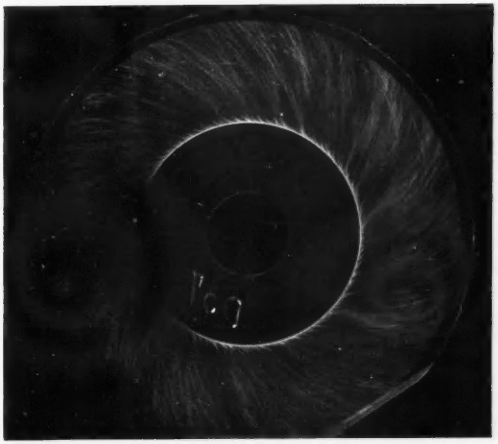


Fig. 15. **Rotating film exposure, showing steady spraying with high oxygen content of flame.**
M = 3·53 ; speed, 3150 rpm ; material, 0·86% C-steel.

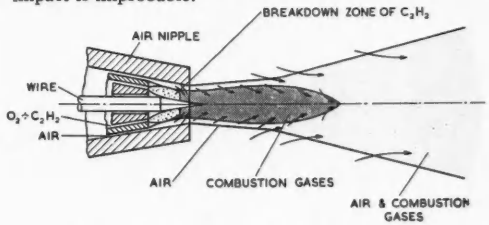


Fig. 16. **Flow diagram in a spray gun.**

Significance of Results for the Improvement of Metal Spraying

In many applications, the metal-spraying process has the disadvantage of producing an oxidised sprayed layer. The present investigation has largely cleared up the causes of such oxidation and has revealed the following possibilities for its restriction :—

(1) *Neutral Heating Flame:*—The correct adjustment of the heating flame cannot be judged by observation. The gas pressures alone, before entry into the burner, do not afford a dependable basis, as even a slight change in the back-pressure will result in an appreciable alteration of the mixture ratio. Such an effect may be produced merely by opening the air valve after the flame has been lighted, or by the blocking of the nozzle mouth.

(2) *The Spray Wire should not be Melted within the Flame Cone:*—The dimensions of the air nipple must be carefully adjusted to the required amounts of gas. The shape of the fuel-gas nozzle and the exit velocity of the fuel-gas oxygen mixture may also exert an influence in this connection.

(3) *Acceleration of the Particles in a Neutral Atmosphere:*—The aim must be to ensure that acceleration should take place within the flame core. For this purpose, the amount of fuel gas must be in a certain proportion to that of the compressed air, so that the oxygen content of the compressed air should not exceed the amount required for the combustion of the carbon monoxide into carbon dioxide and the hydrogen into water vapour. It is advisable to meter the gases.

(4) *Narrow Spray Cone and high Gas and hence high Particle Velocities:*—There is a close connection between these factors, for satisfactory coning of the spray jet depends on high gas velocities at the outlet of the air nipple and its appropriate design and cleanliness.

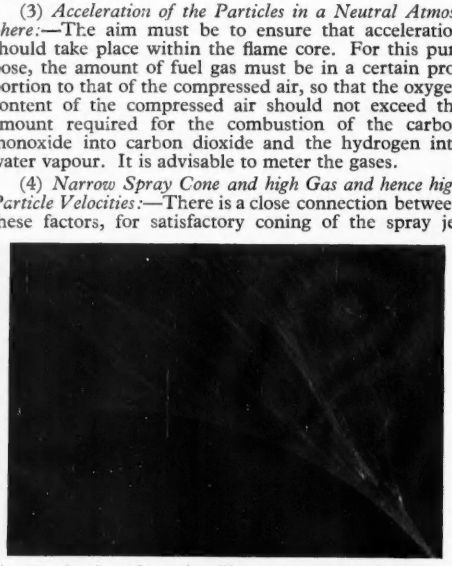


Fig. 17. **Section of rotating film exposure, showing glow of individual particles in the region of the acceleration zone.**
$M = 2{\cdot}23$; speed, 3150 rpm.

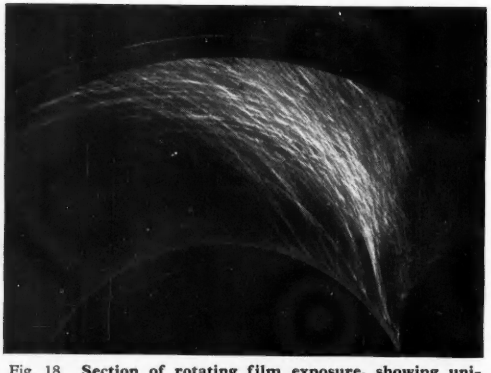


Fig. 18. **Section of rotating film exposure, showing uniformly illuminated track.**
$M = 2{\cdot}23$; speed, 3150 rpm.

Theory of Layer Formation in Metal Spraying

As already mentioned, some authors have held that the adhesion of particles to the workpiece and amongst themselves can be ascribed to " cold welding," but the actual process was then unknown. Others have found that cold welding of metals is possible at room temperature and by pressure alone, provided the surfaces are perfectly clean and are capable of plastic deformation.

In metal spraying, too, satisfactory adhesion is possible only if the surfaces are clean. However, in contrast with cold welding proper, sprayed particles possess a higher temperature than the workpiece and the already existing layer, both of which are practically cold. This fact favours " cold welding," because the deformation

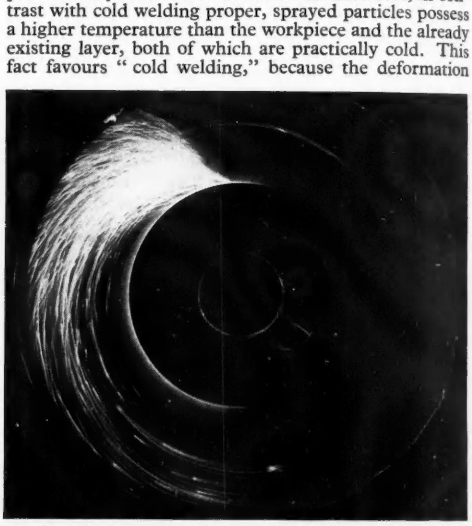


Fig. 19. **Rotating film exposure, showing glow of particles travelling at low speed.**
$M = 1{\cdot}74$; speed, 2800 rpm.

resistance of metals is considerably reduced by higher temperatures, so that welding presumably requires less pressure or weaker impacts, as long as the surfaces remain free from oxides. It is well known that sprayed particles are extensively deformed on impact ; it is therefore an obvious assumption that the oxide film encasing them during their flight bursts at several points on impact, so that clean surfaces can now react upon each other. Hence, the deformation of " hot " particles, arising from the conversion of their kinetic energy on impact, seems to be sufficient to produce the metallic cleanliness and the deformation required for cold welding. This theory is confirmed by the following individual results of other investigators :—

(1) The fact that sprayed layers can withstand various degrees of deformation permits the conclusion that local welding has occurred at different points.
(2) A tensile strength of 12 kg/mm² in sprayed-steel layers has been measured, and can be explained only by welding within the layer.
(3) Sprayed aluminium possesses about 20% of the conductivity of the original material. If each particle were encased in an oxide film (no matter how thin), in view of the well known dielectric strength of aluminium oxide, the passage of current should be completely inhibited.
(4) Cold welding is possible even between metals which do not form mixed crystals. Such metals can also be successfully combined by metal spraying, e.g., steel and aluminium.

The above theory is not contradicted by the results of the present investigation, insofar as oxide formation and impact velocity are concerned.

The Silicone-Putty Slip Clutch and Flexible Coupling

By Milton Adler.

Many of the unusual properties of silicones remain to be explored. In this article, an application of silicone putty is indicated by the author, who is the inventor of the slip clutch and flexible coupling described.

Although silicones have been known in laboratories for over 100 years, it is only very recently that they have been introduced commercially. These silicones, which are neither strictly organic nor strictly inorganic compounds, represent a promising and unusual group of chemicals with many strange properties. Of this group, perhaps the strangest is silicone putty, or "bouncing putty." Silicone putty is related chemically to silicone rubber, but displays many unusual properties. When rolled into a ball, it has considerably greater resilience than the average natural-rubber ball. When subjected to sudden strain or to a hard blow, it shatters; yet, contiguous pieces, of their own accord, will flow together under their own weight and flatten out freely and evenly. Thus, under moderate stress or when adequately confined, silicone putty behaves similarly to a viscous liquid or a soft, plastic solid; under great stress, not adequately confined, it will shatter like glass.

Silicone putty has a specific gravity of approximately 1·1 at 20° C. It is non-corrosive to metals, though slight deposits may build up as a result of plasticiser leaching. It dissolves in polar organic solvents and most water-miscible solvents, and swells in carbon tetrachloride and many aromatic hydrocarbons. It has a resilience of 30% minimum and a rebound of 55 in., using as a basis of measurement a 12-gram ball dropped from 100 in. onto a soapstone surface. Solvents have an effect on rebound; after soaking for 72 hours in various solvents, rebounds were as follows:—Ethylene dichloride, 34 in.; benzene, 43 in.; SAE 10 oil, 50 in.; silicone fluid, 41 in.; concentrated ammonia, 63 in.

Silicone putty exhibits different flow characteristics, depending upon the conditions to which it is subjected. When low pressures are applied, the rate of flow is not proportional to the force. Thus, it acts as a non-Newtonian thixotropic liquid, in which the rate of flow increases slightly with pressure, as shown in Fig. 1.

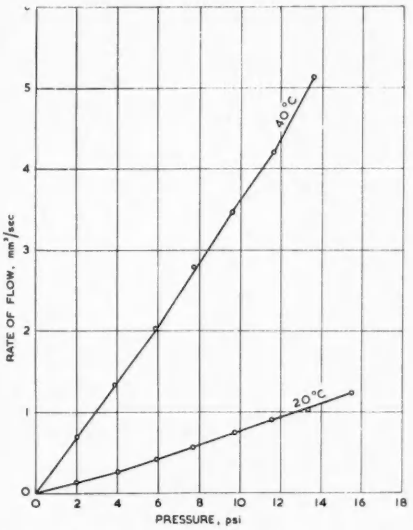


Fig. 1. **Flow curve of silicone putty at low pressures.**

At higher pressures, the putty acts as a plastic solid, since rate of flow is proportional to pressure above a certain yield value. The existence of apparent yield values is shown in Fig. 2, where the lines do not point towards the origin. When pressures are applied suddenly, the putty becomes hard and brittle, and rate of flow increases less than proportionally with pressure. The fluidity of silicone putty increases with increasing pressure, approximately as indicated in Fig. 3.

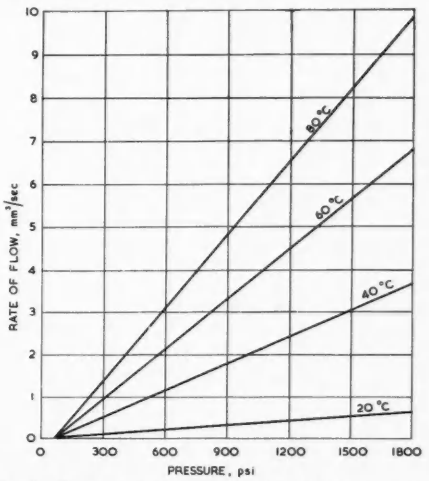


Fig. 2. **Flow curve of silicone putty at high pressures.**

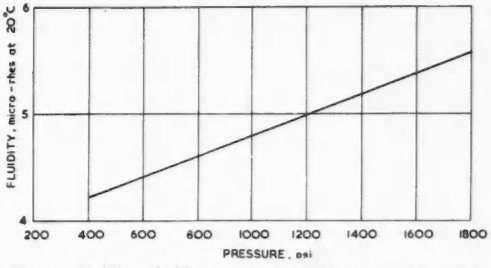


Fig. 3. **Fluidity of silicone putty as a function of pressure.**

Some applications of its unusual properties have already been found for silicone putty, such as damping media, fluid-flow apparatus, sealing and filling compounds in enclosed systems, and sound-transmission devices. However, perhaps one of the most interesting products to be developed around silicone putty is a new type of slip clutch and flexible coupling. The slip clutch is designed to prevent overload and shocks, for starting heavy loads, for absorbing torsional shaft vibrations, and for delivering impulse-free power. The flexible coupling is designed to compensate for both angular and offset misalignment. The separate functions of both the slip clutch and the flexible coupling can, however, be combined into a single unit. The property of silicone putty which causes it to shear under a sudden force, and to flow together again once this force is relieved, is the basic principle applied in this development.

The basic construction of the slip clutch, which is shown in Fig. 4, is as follows:—Casing (1) contains driving member (2), which is drilled at the end (3) to accommodate the shaft of the driving unit and, at the

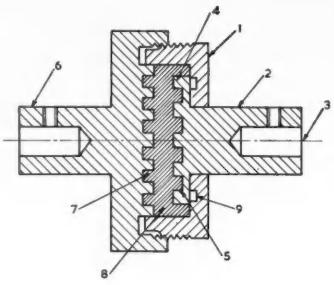


Fig. 4. (left) **Cross-section of slip clutch.**

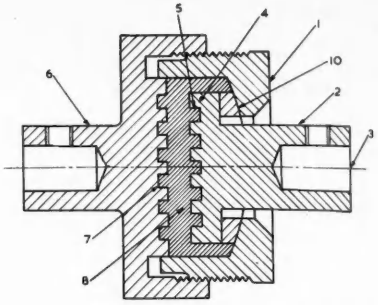


Fig. 5. (right) **Cross-section of flexible coupling.**

other end, has a large face (4), containing serrations (5) across the face. The driven member (6) is screwed to casing (1) and also has a serrated internal face (7). The space between the two faces is filled with silicone putty (8), which is pressed in when the driven member (6) is screwed to casing (1). An annular groove (9) traps any silicone which may leak initially between the back of the face and the casing.

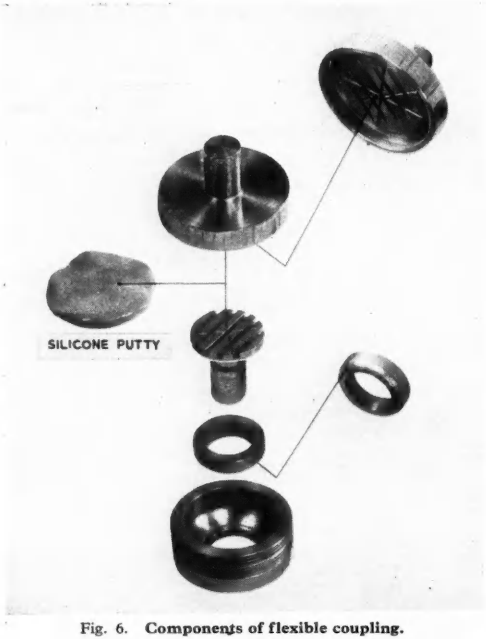


Fig. 6. **Components of flexible coupling.**

In operation, when driving member (2) starts to rotate, the initial torque shears the silicone putty between faces (4) and (7). Almost instantaneously, however, the silicone flows together and causes driven member (6) to rotate. This process of shearing and reforming continues until both members rotate at the same speed. By adjusting the pressure on the silicone putty, the latter can be made to shear at any load within its range, above which it will not have sufficient adhesion to entrain driven member (6). At the same time, it will absorb any torsional vibration and sudden impulses.

The construction of the flexible coupling (Fig. 5) is basically the same as that of the slip clutch, except that casing (1) has a spherical internal seat on which rests a spherical spacer (10). A large clearance is provided between the driving member (2) and the opening in casing (1). This permits the driving member and the spacer to move angularly relative to the casing and allows the driving member to slide on spacer (10) while remaining parallel to driven member (6). The operation of the flexible coupling is similar to that of the slip clutch, except that means are provided to compensate for angular and offset misalignment. Driving member (2) and spacer (10) can move to compensate for misalignment by displacing the soft silicone putty.

One of the designs developed is shown in Fig. 6. This flexible coupling was assembled with various weights of silicone putty and with various spacings between the serrated faces. These combinations are shown by weight in ounces and number of thread turns from the closed solid condition in the graph in Fig. 7. One test consisted of operating the coupling with one shaft fixed in such a manner that its torque could be measured while the other shaft was rotated at slow speed. This test provided information on the driving torque with relation to slip speed, and the results are plotted in Fig. 7. The terminal point of each curve represents the maximum torque developed, the curves remaining essentially flat or dropping off beyond the plotted points.

In operation tests driving a prony brake, torques of approximately half the capacity indicated on the graph were developed, before leakage or complete failure to drive occurred. Results of the first prony-brake tests

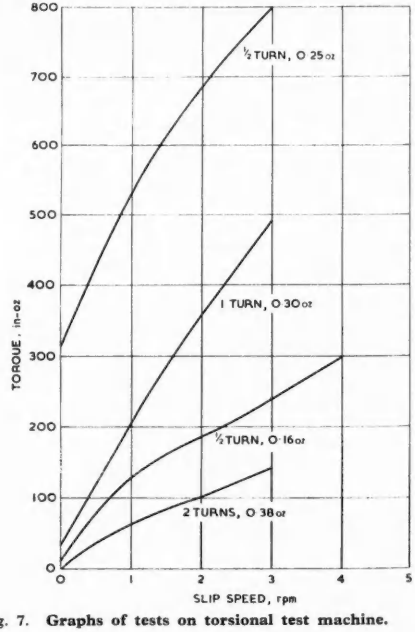


Fig. 7. **Graphs of tests on torsional test machine.**

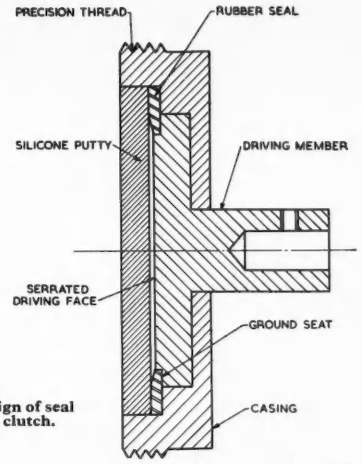


Fig. 8. **Design of seal for slip clutch.**

showed that torques corresponding to roughly ¼ hp at 1750 rpm represent the capacity of this coupling.

In addition, the coupling was assembled between a motor and a dynamometer and operated at ¼ hp. This was with 0·30 oz of material and one turn opening, which, from previous tests, was found to be the best combination. After approximately three hours operation, the coupling failed completely and, because the motor continued to drive, the silicone deteriorated to such an extent that it would no longer flow together. In addition, it was found that, with considerable misalignment, the silicone putty tended to leak from the coupling.

It was obvious, therefore, from the numerous tests conducted, many of which were carried out at the Lord Manufacturing Co., of Erie, Penn., that the two problems to be overcome were the leakage problem, and the failure of the silicone putty to heal after being sheared at certain speeds. Both problems have now been overcome. The problem of leakage was eliminated by using suitable seals. The seal now used with the slip clutch is shown in Fig. 8. The rubber seal is bonded or securely fastened to the casing, and presses against a ground seat around the driving face. The pressure against the seat is built into the rubber seal, or is added by means of a spring, of the type employed in rotating-shaft seals.

Healing of the putty was accomplished by redesigning the serrated faces in such a way that the serrations are shallower and much closer together. This construction allows for more shearing area of putty against putty.

The ability of this coupling to drive after having sheared eliminates the necessity of the conventional shear pin. In addition, its simplicity and compactness should make it useful in many applications.

BELGIUM

Investigation of a Convergent-Divergent Nozzle in a Supersonic Wind Tunnel

By J. J. GINOUX. (From *Revue Universelle des Mines*, Series 9, Vol. 10, No. 4, April 1954, pp. 85-92, 12 illustrations.)

In a supersonic wind tunnel, air velocity is increased from subsonic to supersonic values. It might therefore be thought that the model will cross the sound barrier in the same way as an aircraft in actual flight. This, however, is not the case, as is shown in the following theoretical and experimental investigation.

ALTHOUGH a classification of wind tunnels could be made by comparing relative air velocities obtained in the test chambers, the important factor is not the velocity of the body in motion (or its relative air speed), but the ratio of this velocity to the local velocity of sound, i.e., Mach number M. Using this as a basis, it is possible to classify wind tunnels as follows :—

Low-speed :—	$M < 0{\cdot}3$
Subsonic :—	$0{\cdot}3 < M < 0{\cdot}8$
Transonic :—	$0{\cdot}8 < M < 1{\cdot}2$
Supersonic :—	$1{\cdot}2 < M < 5$
Hypersonic :—	$5 < M$

It will be seen in the following that a different duct design is required for each type of wind tunnel. It should, however, be remembered that, in the case of a low-speed wind tunnel, which employs a convergent nozzle, it is impossible to obtain supersonic speeds in the test chamber, assuming that there is no limitation to the power available. To attain supersonic speeds, it is necessary to arrange after the convergent section a divergent section, so as to obtain a " convergent-divergent " nozzle.

THEORETICAL ANALYSIS OF A CONVERGENT-DIVERGENT NOZZLE

Convergent-divergent nozzles for supersonic wind tunnels are generally designed with rectangular cross-sections. With these, calculations are easier than for nozzles of circular section.

A schematic section of the nozzle in the Rhode-St. Genèse supersonic wind tunnel, operated by the Belgian Aeronautical Research Board (C.N.E.R.A.), is shown in Fig. 1. The divergent portion is followed by the test chamber, which is of constant cross-section. The inlet and outlet section of the nozzle are denoted by S_i and S_o, respectively, and the " throat " or minimum section by S_t. Any section S of the test chamber is assumed to be at a distance x from the throat, taken as the origin of the x-values used as abscissae.

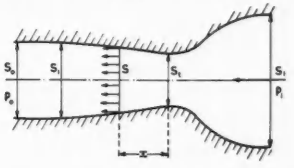


Fig. 1. **Schematic section of convergent-divergent nozzle.**

When the axial compressor used for circulating the air is rotating at a speed of N rpm, there is a difference in pressure $p_i - p_o$ between the inlet and outlet of the nozzle. This pressure difference increases with N. However, the wind tunnel is provided with a pressure control valve, which maintains p_i constant for all values of N. Thus, any increase in compressor speed results only in a reduction in p_o at the nozzle outlet.

It is of interest to consider the motion of the air in the nozzle while $p_i - p_o$ increases from zero, i.e., when N increases from zero. The calculation can be made by assuming uniform flow conditions, i.e., a constant value of air velocity for all points in the same cross-section. This enables a qualitative study to be made of the flow, and the results of this study have been verified experimentally.

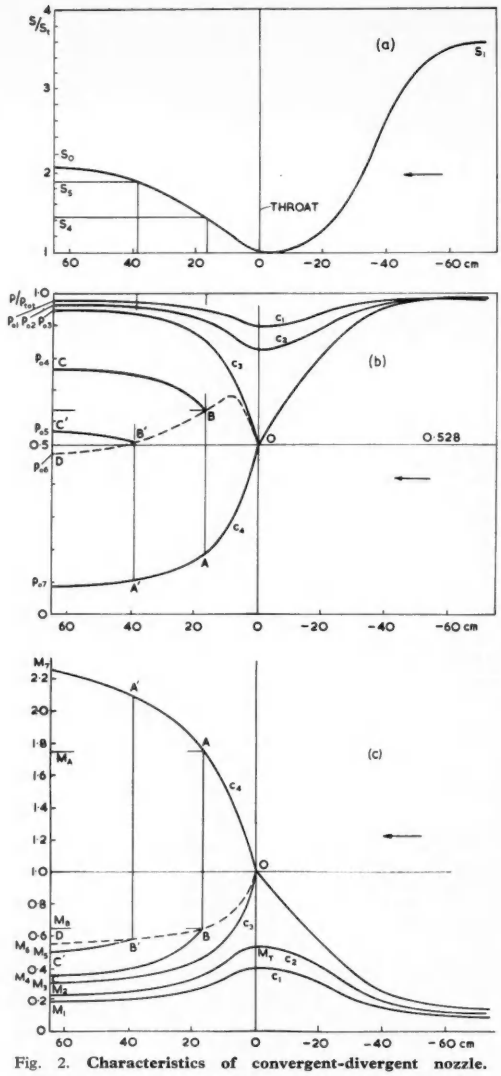


Fig. 2. **Characteristics of convergent-divergent nozzle.**

The theory of one-dimensional flow in nozzles has been developed by the author in another paper*. It has been applied to the nozzle of the Rhode-St. Genèse wind tunnel, and the results obtained are shown as functions of the throat distance x in Figs. 2a, 2b, and 2c. The nozzle shape is given in Fig. 2a and is represented by the curve S/S_t, where S = height of cross-section at any point x, and S_t = height of throat section. The pressure distributions for various values of the outlet pressure p_o are represented in Fig. 2b by curves of the ratio p/p_{tot}, where p = pressure at x, and p_{tot} = total pressure (i.e., the pressure which would be obtained at a stagnation point situated ahead of the nozzle). The corresponding curves of Mach numbers are shown in Fig. 2c. The flow is subsonic or supersonic, according to whether the point considered is situated below or above the straight line $M = 1$.

*J. J. Ginoux: Dynamics of compressible fluids, one-dimensional and two-dimensional flow. C.N.E.R.A., 11, rue d'Egmont, Brussels.

These graphs can be used to describe the variation in flow conditions in the convergent-divergent nozzle, when the outlet pressure p_o is gradually reduced, while the inlet pressure p_i is maintained constant.

When $p_o = p_i$, the air is stationary. When $p_o = p_{o1}$ (a value slightly below p_i), the pressure p and Mach number distributions are indicated by the curves c_1 in Figs. 2b and 2c. The pressure decreases in the convergent portion, reaching a minimum value at the throat, and rises again in the divergent portion of the nozzle. In contrast, the c_1-curve of the Mach numbers rises (from right to left) in the convergent portion, reaches a maximum M_T at the throat, and decreases thereafter, finally reaching a value M_1 in the test chamber. The flow is subsonic throughout.

When $p_o = p_{o2}$ (lower than p_{o1}), the c_2-curves are similar to the c_1-curves, but with higher Mach numbers in the throat and test chamber. By gradually decreasing the outlet pressure, a value p_{o3} is reached, for which $M = 1$ at the throat section. At all other points, however, the air speed remains subsonic.

At a lower value p_{o4}, the velocity distribution in the divergent portion is represented by the curve *OABC* (Fig. 2c). The velocity becomes supersonic after passing the throat, reaches a peak value M_A and then drops suddenly to a subsonic value M_B, this being followed by a gradual decrease to a value M_4, which is reached in the test chamber. The discontinuity in velocity in section S_4 is accompanied by a sudden recompression of the fluid with the pressure (curve c_4 in Fig. 2b) rising suddenly from p_A to p_B. This type of discontinuity is known as a "normal shock wave."

If the pressure at the outlet is further decreased, for instance, to a value p_{o5}, the variation in velocity will be as indicated by a curve which passes through the points *O*, *A'*, *B'*, and *C'*. The normal shock wave is thus displaced in the downstream direction, and its intensity ($M_{A'} - M_{B'}$) has increased. When p_o is reduced to p_{o6}, the shock is situated in a section S_1 at the inlet of the test chamber. The discontinuity represents a drop in velocity ($M_7 - M_6$) and a sudden rise in pressure from p_{o7} to p_{o6}. Thus, for any value p_o of the outlet pressure, between p_{o3} and p_{o6}, there is a shock wave in the divergent portion of the nozzle, and its intensity is such that the pressure in section S_1 is also p_o. The position of the discontinuity in the divergent portion is stable, i.e., stationary, as long as p_o remains constant. By decreasing the pressure at the outlet to a value p_{o6}, it is therefore possible to increase the air velocity in the test chamber to a subsonic value represented by M_6.

It can be shown that a normal shock wave cannot be stabilised in a constant section. Consequently, by reducing p_o to a value slightly below p_{o6}, the shock wave will travel through the test chamber and leave behind it a supersonic flow, with a Mach number M_7 and a pressure p_{o7}. The nozzle is then in its operating condition. In the test chamber, the air velocity thus passes suddenly from a subsonic value M_6 to a supersonic value M_7, owing to the passage of a normal shock wave. In other words, the velocity in the test chamber is never sonic, i.e., the model does not pass through the sound barrier during tests in a supersonic wind tunnel.

The above analysis also shows that the final Mach number attained at the test chamber inlet always has the same value M_7. To obtain other values, it would be necessary to alter the shape of the nozzle arrangement. This explains the difficulties encountered in trying to carry out tests at different supersonic Mach numbers.

The appearance and the position of the shock wave, after it has passed through the constant section of the nozzle, depend on the shape of the ducting after the test chamber. If the nozzle opens suddenly into a duct of larger section, two oblique shock waves are formed

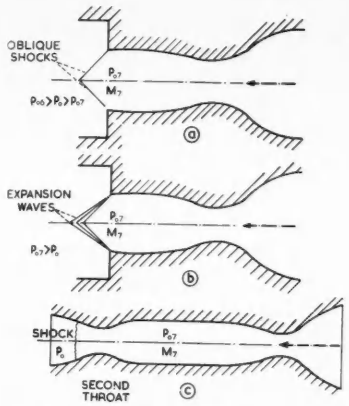


Fig. 3. **Effect of duct shape on appearance and position of shock wave.**

(Fig. 3a). Their slope increases and their intensity decreases when the outlet pressure is reduced to values below p_{o6}. When $p_o = p_{o7}$, these two shock waves vanish and transform into two expansion waves symmetrical with respect to the centre line of the nozzle (Fig. 3b). If the nozzle is followed by a second convergent-divergent duct, with a second throat section (an arrangement frequently employed), the normal shock wave is stabilised in a section of this second nozzle (Fig. 3c), the position of the discontinuity depending on the value of the outlet pressure p_o.

Experimental Study of a Convergent-Divergent Nozzle

The above theory was verified by measurements carried out in the Rhode-St. Genèse supersonic wind tunnel. It can be shown that the Mach number for any point in the flow can be calculated if the corresponding static pressure and the total pressure p_{tot} (for a stagnation point with isentropic conditions) are known.

The total pressure is practically constant at all points in the flow when there is no shock wave. It is sufficient, in this case, to measure pressure at any point where the velocity is subsonic, near the centre line of the nozzle. The static pressures were measured at a large number of points on the vertical walls of the nozzle. However, in the presence of a shock wave, the total pressure varies because of the change in entropy across the discontinuity. It is then necessary to measure the total pressure after the shock wave.

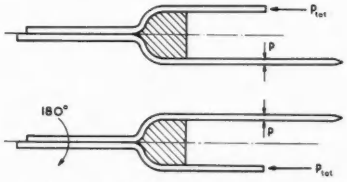


Fig. 4. **Details of special pressure-measuring element.**

The pressure-measuring element developed by the author is shown in Fig. 6. It consists of two tubes, one of which has an open end for measuring the total pressure p_{tot}, whereas the other has a lateral opening for measuring static pressure p. The branches are connected to two manometers by means of plastic tubing. The two extensions are brought together, as shown in Fig. 4, and pass through a supporting sleeve extending in the axial direction of the nozzle. This sleeve is mounted in two bearings in which it can slide axially and also rotate through 180 deg. during the test, these movements being obtained by means of controls situated outside the duct system, which is air-tight and operates at sub-atmospheric pressures. The measuring element can thus be moved to different positions. Furthermore, by rotating it through 180 deg. about its axis, the two branches can be successively brought to the same point in the flow.

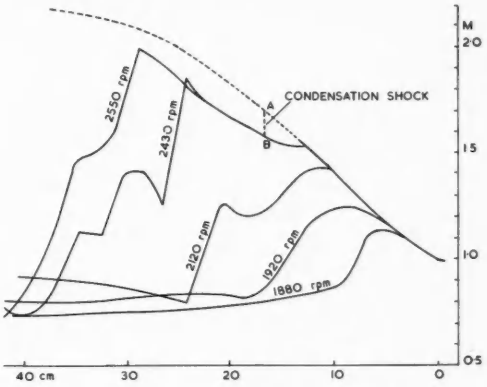


Fig. 5. **Experimental results obtained with special pressure-measuring element.**

The results of the investigation made with this measuring element are given in Fig. 5 for decreasing values of outlet pressure p_o, i.e., for increasing compressor speeds N. The curves for constant rpm-values are plots of Mach numbers against the distance x [cm] from the throat section, in the divergent portion of the nozzle. The slopes (instead of vertical lines) at the discontinuities are due to interaction between the measuring element and the shock waves. The results obtained confirm the foregoing theory and show that :—

(1) The discontinuity is localised in the divergent portion of the nozzle and comes closer to the test chamber as the outlet pressure is decreased.

(2) The flow in the test chamber remains subsonic until the shock wave passes through the chamber, after which the flow suddenly becomes supersonic.

(3) In certain sections of the test chamber, the supersonic value of the Mach number is always the same, irrespective of the operating conditions in the nozzle.

The tests also showed that the subsonic Mach numbers obtainable are somewhat higher than those predicted by the one-dimensional theory, which gives only a qualitative assessment of the flow conditions.

Fig. 5 shows that the supersonic Mach number in the test chamber was approximately 2·0, instead of 2·2 for which the nozzle was calculated. This is due to the existence of a "condensation shock wave,"* situated between the throat and the test chamber, which produced the drop AB in Mach numbers (Fig. 7). The dotted line represents the conditions which would have been obtained in the absence of condensation.

The temperature of the air decreases when the flow velocity increases. In the nozzle investigated, the temperature drops to $-50°$ C in the neighbourhood of the throat and to approximately $-100°$ C in the test chamber. For this reason, the air is supersaturated with water and, under certain conditions occurring after the throat section, a sudden condensation of water vapour takes place. The intensity of the condensation shock depends on the degree of humidity of the air, the temperature, etc. As a result, the supersonic Mach

*J. J. Ginoux : On the presence of condensation shock waves in the M = 2·2 nozzle of the supersonic wind tunnel. Report B.B.1 of C.N.E.R.A.

number of the test chamber varies from one test to another and affects the uniformity of flow. To overcome this drawback, an air-drying unit is being developed for incorporation in the wind tunnel.

From the pressure measurements obtained on the nozzle walls, it was found that the shock waves in the divergent portion during the preliminary transition period were oblique. It was also shown that there was a breaking away of the boundary layers on the nozzle walls, owing to recompression through the shock.

Finally, photographs were taken through glass windows in the nozzle walls of the shock waves, recording being made with a high-speed camera. The shape of the shock wave was seen to be affected by interaction with oblique shock waves caused by irregularities in the walls ahead of the constant section of the nozzle.

U.S.A.

Control of Radiant Heat by Surface Finish

By R. M. LEEDY. (From *Westinghouse Engineer*, Vol. 14, No. 4, July 1954, pp. 147-151, 8 illustrations.)

A clear lacquer film, only 80 millionths of an inch thick, increases the ability of aluminium to absorb or emit radiant heat by a factor of about ten. Similar, or even more unusual effects, can be produced by other coatings, and on other materials. The potential applications of such surface finishes are innumerable.

HEAT transfer can be effected by conduction, convection, and radiation. In most applications, more than one of these factors are involved. When studying practical applications, therefore, it should be borne in mind that any one of the above mechanisms of heat transfer may overshadow the others. Even when considering radiation alone, other factors must be taken into account, such as the continuous transfer of radiant energy from a body to and from its surroundings. For example, the feeder pipes to a domestic hot-water heating system radiate heat to the walls of a basement. Although the walls are at a lower temperature than the pipe, they also radiate heat, a certain portion of which is absorbed by the feeder pipes. Calculation of the net loss in heat by radiation, therefore, requires consideration of the temperatures of both the wall and the pipe, as well as the emissivity and absorptivity of their respective surfaces.

Surface absorptivity is a measure of the ability of a material to absorb radiant heat. A theoretical "black body" absorbs all incident radiation at all wavelengths and reflects none. Although a perfect black body does not exist, some surfaces, such as a coating of lampblack, reflect such a minute portion of any incident radiation that they approach ideal black-body conditions. A good heat-absorbing surface is simultaneously a good emitter of heat energy (loss of heat by outgoing radiation) at the same wavelength. By definition, the emissivity of a given surface is the ratio of the intensity of radiation emitted by that surface to that emitted by a black body under the same conditions of wavelength and temperature. For example, a surface of lampblack mixed in waterglass has an emissivity of approximately 95% of that of a perfect black body. In contrast, a commercially polished copper surface at about the same temperature has an emissivity of approximately 3% of that of a perfect black body.

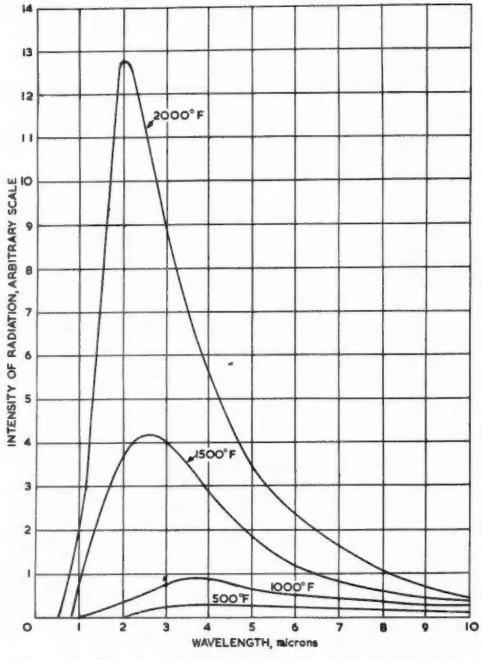


Fig. 1. **Black-body radiation curves for different temperatures.**

The intensity of radiation of any surface varies with wavelength and temperature. A few black-body radiation-distribution curves for different temperatures are shown in Fig. 1. The area under each curve represents total spectral energy emitted at a given temperature. Increasing the temperature causes an increase in the intensity of radiation at any given wavelength and a decrease in the wavelength at which maximum energy emission occurs. Lampblack gives similar curves.

In general, the emission curve for any practical surface lies below that for a black body at the same temperature. However, some materials have quite different emission characteristics. Such materials are termed selective emitters, and their emissivities vary widely at different wavelengths. White cloth is a poor absorber of radiation from the sun (low emissivity at short wavelengths) and at the same time is a good emitter of body heat (high emissivity at long wavelengths). The coolness of white clothing in summer, therefore, can be ascribed to its high reflectivity for solar radiation and its low reflectivity for the heat generated by the human body.

Zinc oxide is also a selective emitter. Its emissivity is 97% at a temperature of 125° F (corresponding to a wavelength of 8·8 microns) and is only 14% at 5000° F (0·95 micron), while its emissivity is 18% at solar temperatures (0·60 micron). An emissivity value at a given temperature does not necessarily mean that the body itself is at that temperature; instead, it may indicate the ability of the body to absorb radiant heat from a second body operating at that temperature.

Two important considerations in dealing with radiant-heat absorption and emission problems are: (a) For most solids, absorption (or emission) is a surface phenomenon; and (b) the colour of a surface is not a measure of its ability to absorb or radiate heat. For example, bright copper has an emissivity of approximately 7% at 200° F and an emissivity of 44% if the surface is tarnished (Fig. 2). The curves show that the emis-

sivity of bright copper can be increased from 7 to 37% merely by applying a thin coat of clear lacquer. The effect of various thicknesses of lacquer films on the emissivity of aluminium is shown in Fig. 3. Experiments have shown that the emissivity of polished iron (0 to 100° F) can be increased to as high as 83% by applying a very thick layer of oil. Similarly, a 0·0008-in. layer of oil results in an emissivity of 22%, and a 0·008-in. layer of oil increases the emissivity to 81%. A thin coating of aluminium oxide on aluminium can change the emissivity from 3% to a value as high as 80%, as shown in Fig. 3. Note that the thickness of the oxide coating becomes less effective after a value of approximately 70% is attained.

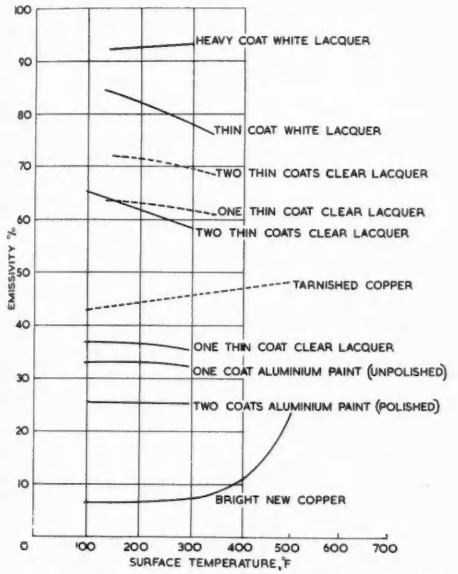

HEAVY COAT WHITE LACQUER
THIN COAT WHITE LACQUER
TWO THIN COATS CLEAR LACQUER
ONE THIN COAT CLEAR LACQUER
TWO THIN COATS CLEAR LACQUER
TARNISHED COPPER
ONE THIN COAT CLEAR LACQUER
ONE COAT ALUMINIUM PAINT (UNPOLISHED)
TWO COATS ALUMINIUM PAINT (POLISHED)
BRIGHT NEW COPPER
EMISSIVITY, %
SURFACE TEMPERATURE, °F

Fig. 2. **Emissivity of bright copper (solid lines) and tarnished copper (dotted lines) with various surface finishes.**

Dead black, black, dark green, white, black enamel, and white enamel paints all have practically the same emission characteristics when coated on a body operating at about 212° F. This is the reason why the efficiency of a steam radiator painted with conventional household paints is equally good, regardless of the colour. However, when considering such finishes as aluminium and bronze-coloured metallic-pigmented paints, lacquers, etc., the situation is somewhat different. Since most metallic-pigmented finishes have emissivity values considerably lower than those of standard household paints, a household hot-water or steam radiator painted with aluminium paint might be expected to be less efficient than one painted with enamel. Actually, the net difference in efficiency may be negligible, or in some instances in favour of the lower-emissivity finish. Approximately 70% of the heat dissipated from a two-column radiator of thirteen sections is transferred to the room by convection, whereas 30% is dissipated by radiation. Radiant heat is useful mainly to the object upon which it impinges and is generally lost to the walls, ceiling, etc. A low-emissivity finish on the radiator could, therefore, decrease the amount of heat radiated directly to the walls and, in turn, conducted to the cooler outside wall. Another variable is that the emissivity of metallic paints can be affected by the physical size and shape of the metallic particles, as well as by the composition of the vehicle used to carry the metal. For example, an aluminium paint consisting of aluminium powder and a low-solids-content varnish might have an emissivity as low as 25%; on the other hand, an aluminium paint with an emissivity as high as 60% can be made with aluminium paste (extremely fine powder mixed with liquid) and a suitable varnish. An excess of resin or an extra coat of clear resin or lacquer on the surface further increases the emissivity.

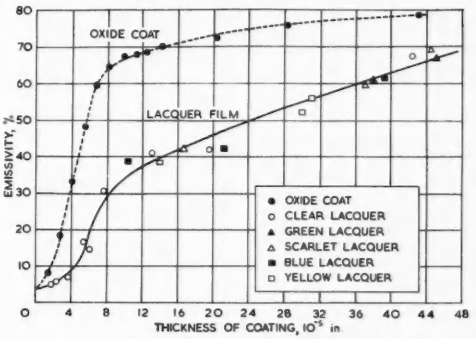


Fig. 3. **Effect of various thicknesses and colours of lacquer films on the emissivity of aluminium.**

The curves in Fig. 3 substantiate the fact that colour is not a criterion for predicting emissivity. They show that the increase in emissivity resulting from various thicknesses of organic dyed lacquers applied to aluminium is essentially the same for clear, green, yellow, blue, and scarlet colours. However, lacquers pigmented with such materials as zinc oxide, lead oxide, or lampblack may show an entirely different " thickness versus emissivity " relationship.

APPLICATIONS.

Jet Engines:—One means of lowering the combustion-wall temperature in jet engines is to maintain low emissivity of the surface facing the combustion gases and to increase the emissivity of the outer wall. The low-emissivity surface minimises the amount of radiant heat absorbed by the combustion wall, and the high-emissivity outer surface facilitates the dissipation of whatever heat is absorbed. Ceramic finishes have been developed which can raise the emissivity of combustor materials to over 90% at temperatures of 800 to 1100° F.

Cooking Appliances:—Uniform heat distribution on a large grill presents a problem. One means of solving this problem is to coat selectively the bottom surface of the grill with materials which will increase the emissivity at desired locations.

Similarly, thermal voltage-control regulators for toasters have been made more efficient by using controlled heat-absorption surface finishes for the bimetals. These finishes increase the speed of reaction of the thermostat, and prevent the thermostat from losing calibration owing to the possibility of an untreated bimetal becoming dirty or oxidised during normal use.

Electronic Tubes:—In certain applications for radiant-heat-controlling finishes, other engineering advantages are gained simultaneously. An important common example is found in receiving tubes and industrial electronic tubes. The carbonised nickel surface used on some vacuum-tube anodes results in a high thermal emissivity coating, which dissipates heat and thereby reduces back electron emission. Also, the back electron emission is still further reduced by the tendency of the carbon to entrap any barium sublimed from the filament coating to the plate, and thus render it inactive as an electron emitter. This entrapment of barium or other high electron-emission materials is not thoroughly understood, but it does increase tube efficiency by

preventing these materials from redepositing on other elements of the tube, such as grids. Pure nickel, nickel-plated steel, and nickel-clad steel have all been examined for this application. Basically, the surface treatment involves coating the nickel surface with nickel oxide and subsequent reduction of the oxide to pure nickel, resulting in a matte finish with a thermal emissivity about half that of a black body. The thermal emissivity is further increased to approach that of a black body by carbonising. The carbonising treatment can be carried out during the same process in which the nickel matte surface is formed, or as a completely separate operation

Aluminium-clad steel has been used for vacuum-tube parts in Europe for a number of years and is now being used in the U.S.A. When steel is clad with aluminium and subsequently heated to about 1200° F for a suitable length of time, the two metals diffuse, resulting in a conversion of the surface to compounds of iron and aluminium. The surface is rough, black in colour, and has a thermal emissivity of 80 to 85%. In practice, tube parts, such as anodes and shields, are formed from the clad material, are welded when necessary, and then heated to form the high thermal emissivity iron-aluminium layer.

Electromagnets for TV Tubes:—The focus coils for some television sets are doughnut-shaped electromagnets enclosed in a metal case. Without a finish on this case, the coil operates at a temperature of 130° F. Treating the surface with a black oxide finish cuts the operating temperature to about 97° F. The electronic circuit would be affected by the higher temperature, causing an increase in time for the focus control to become stabilised. Here again, the finish has resulted in multiple benefits, as the treatment also offers corrosion protection.

Transformers:—Another dual-purpose finish incorporating corrosion-protection properties, together with emissivity control, could be helpful in dissipating heat from some types of transformers. Convection sometimes overshadows radiation to the extent that the radiant-heat transfer is not always of major importance. Thus, for example, a wind velocity of a few miles per hour may offset the effect of solar radiation impinging on an object. Consequently, for some applications, a high-emissivity surface, to dissipate the heat from a transformer, may be more important than a highly reflecting (low-emissivity) surface in warding off solar radiation.

Capacitors:—Outdoor capacitors are heavily metallised with zinc, to prevent rusting of the cases during long periods of exposure to weather. The freshly metallised surface does not radiate the losses as well as the previous painted finishes, as the emissivity of freshly sprayed zinc is low. A finish coat of a high-emissivity lacquer is applied to reduce operating temperatures and at the same time to provide some added corrosion protection and better appearance.

Conclusions

As mentioned, such advantages as reduction in operating temperature of capacitors, increase in speed of response of thermostats, and uniform distribution of temperature of heating grills are obtained by appropriate selection of surface finishes. In addition, multiple benefits, such as corrosion protection, improved appearance, and controlled heat absorption can often be obtained in one finish. An important consideration is that absorption or emission characteristics of some materials (selective emitters) change as much as 80%, according to the wavelength of the incident rays, the wavelength in turn being dependent on the temperature of the emitting body. For the proper selection of finishes, a designer should review the principles of heat transfer and should acquaint himself thoroughly with its mechanisms. With proper consideration of all aspects, surface finishes can be a useful tool in controlling radiant-heat absorption or emission.

THE AUTOMATIC CONTROL OF MACHINE TOOLS

(*Concluded from page* 308)

of the point at which the tool was to end its motion and the speed with which it was to travel in each direction. Each of these was fed in digitally in the form of a voltage from a decade voltage divider. The voltage divider actually consists of taps on a toroidally wound transformer. It has been found that the voltage from these taps is proportional to the number of turns within one part in 100,000, or better. Even this is not a limitation. By a little manipulation of high- and low-speed systems, it is possible to operate to much closer tolerances than this. The speeds when the machine was built were not in as close steps as they could have been.

At the time, it was contemplated that the machine would handle straight turning and rough tapers. Actually, it is possible, with this system, to cut tapers with a tolerance of perhaps a tenth of a degree for whatever length is desired. If it is necessary to have closer tapers than this, they can be cut in steps; in other words, a short section can be cut and the machine re-positioned. This would leave a visible ring on the work at each such point, but it still would be everywhere within a reasonable tolerance.

As built, this machine was capable of driving the carriage at about 60 ipm, at no load. Maximum power was delivered at about half this speed. The accuracy of the machine, or at least its reproducibility, was very good. Successive pieces did not vary by more than 0·0002 in. in diameter.

Another example of an automatically controlled machine tool is a Fellows gear shaper, to which servo-mechanisms have been added for cutting non-circular gears. The principle of operation is that any non-circular gear can be generated by a rolling of the pitch line of a circular gear along the desired pitch line of the non-circular gear. On the gear shaper, the motions available are rotation of the work spindle, rotation of the cutter spindle, and motion of the cutter spindle towards the work spindle. In normal operation of the gear shaper, the two spindles merely are geared together in the proper ratio; the cutter spindle is driven towards the work spindle during a portion of the rotation, while the cutter is fed into the work, and then both proceed to rotate at constant centre distance.

In the non-circular case, it is necessary to rotate the work spindle and the cutter spindle at relatively varying rates and, at the same time, to drive the cutter spindle towards or away from the work spindle. The method of doing this is to divide up the required motion of each of these into steps. The steps of work rotation are 2 min. of angle; the steps of cutter rotation are equivalent to 0·01 of a tooth, which is 0·15 deg. on a 24-tooth cutter, and the steps of motion of the cutter spindle toward the work spindle are 0·00025 in.

Computation is a little involved, but ends up by making steps of any one or any combination of the three motions. The principal features of the system are the use of standard components. There is little special work involved, as the film is 16 mm and is run through an ordinary projector, from which the intermittent motion has been removed. As each spot passes over a phototube, it causes operation of a relay and a stepping switch, which is not used as a switch but is geared to a synchroniser. The three synchronisers transmit to receiving synchronisers controlling servo-mechanisms on the gear shaper. Operation is not particularly rapid.

The last device to be considered is one which operates from punched cards, on which successive co-ordinates are punched. These co-ordinates are then reduced to the fourth differences between co-ordinates, which, of course, do not have as many figures as the co-ordinates themselves. These differences are fed into a group of roller and disc integrators, which integrate the position while the work rotates.

Scale Formation and Corrosion Cracking in Heat-Resisting Alloys for Gas Turbines

By P. GALMICHE. (From *La Recherche Aéronautique*, No. 39, May-June, 1954, pp. 45-53, 22 illustrations.)

THE nature and magnitude of the stresses to which the various components of a gas turbine in contact with combustion gases are exposed vary considerably, according to the component and the type of turbine.

As a rule, combustion chambers have to withstand the highest temperatures, while turbine blades are subjected to very considerable creep and fatigue stresses. At the same time, operating conditions are very different, as between stationary and marine gas turbines on the one hand, and aviation gas turbines on the other. The first two operate at relatively low temperatures, using fuel oil with a high content of impurities, such as sulphur, sodium, and vanadium, which tend to increase the rate of corrosion at high temperatures. Aviation gas turbines operate at temperatures close to the limiting temperatures of their components, so that an accidental increase of the order of 100° C, even for a short time, may have serious consequences, such as incipient corrosion cracking, and aggravation of creep, which may lead to contact between the rotor blades and the stator. Accordingly, only high-quality fuel is used, in which the main impurity, sulphur, must not exceed 0·5%.

The gases coming into contact with the turbine blades are in principle oxidising agents though, in fact, it would appear that sometimes they may be reducing agents. This leads to aggravation of some corrosion effects. For example, abrupt starting or acceleration is particularly dangerous, because the injectors deliver the fuel to the combustion chambers immediately, whereas the compressor takes time to attain the speed required for the new output. Any irregularity in the flame or its dilution with secondary air causes the formation of gas which may be of a reducing and particularly corrosive nature.

The direct effects of corrosion manifest themselves by scaling of the metal surface, involving a loss of metal, and by the penetration of corrosion products along the grain boundaries. The consequent formation of the oxide layer modifies the underlying material through loss of protective elements, such as chromium and aluminium, while the penetration of corrosion in depth corresponds to a notching effect, the strength of the corrosion products being practically nil. There seems to be no explanation for some turbo-jet blade failures other than progressive transgranular cracking arising from initial intergranular corrosion.

In all alloys used in gas turbines, the principal protective element against corrosion is chromium, which is present in proportions of roughly 15% to 35%. The alloys are ductile, generally malleable, and their melting points are high. There is a minimum chromium content for various operating temperatures, beyond which oxidation rates vary only slightly. The content is reduced, particularly in the case of alloy steels, by the presence of, for instance, aluminium, silicon, or nickel, but is increased by the presence of such elements as carbon, which transforms part of the chromium into stable compounds.

The behaviour of various heat-resisting alloys under the action of combustion gases has been investigated, and the influence of different chromium contents in the surface layers determined, in an effort to define the causes and mechanism of corrosion cracking at high temperatures and to suggest means of combating it.

The alloys investigated were various nickel-chromium alloys, type 80-20, modified, containing titanium and aluminium, Nimonic 75, 80, 90, and 95, and Oneral, which is a new cobalt-chrome-based casting alloy for blades.

Most of the samples were electrolytically polished before corrosion testing. The surface of some of the samples was chromium-enriched by gas cementation, while in others the chromium content of the surface was reduced. By means of the O.N.E.R.A.* gas-cementation process, it was possible to obtain surface layers with progressively decreasing chromium contents, the outermost layer containing between 20% and 60%.

Special test apparatus was evolved by O.N.E.R.A., consisting essentially of a gas generator and an electric furnace to raise the gas to the test temperature. The fuel flows at a constant rate from a raised tank through a capillary into a vaporisation chamber, where it is mixed with primary combustion air from a rotary supercharger. Combustion takes place when the mixture leaves this chamber; the resulting combustion gases can be mixed with secondary air, from the same supercharger, provision being made for adjustment of the relative quantities. A blower enables the samples to be cooled periodically by a blast of air, so as to duplicate the effect of thermal shock.

By controlled variation of the primary and secondary air outputs, the samples can be subjected to corrosive atmospheres similar to those in a gas turbine, i.e., to purely oxidising combustion gases, to the products of incomplete combustion, and to such products diluted with an excess of air.

In general, the fuel used was kerosene, with a sulphur content of 0·5%, but some tests were carried out with fuels containing up to 5% of sulphur, while pure gasoline was used to obtain absolutely sulphur-free combustion gas.

Corrosion tests normally lasted 100 hours, at temperatures between 700° and 900° C, both time and temperature being increased in special cases. The progress of corrosion was followed by determination of the metal lost through scaling and by micrographic examination. The modification of the composition of the corroded zones was determined by spectroscopic analysis, together with electrolytic polishing and measurement of micro-hardness.

EXPERIMENTAL RESULTS

(1) Loss of Metal by Scaling

(*a*) *Influence of conditions of corrosion:*—In the case of the alloys tested, temperature is the main factor affecting rate of corrosion. The composition of the combustion gases produces only a limited effect, at least insofar as aviation fuel is concerned. The differences observed between rates of scaling in air and in the various combustion gas atmospheres are of the same order as the scatter noted in the results (20% to 30%). In all cases, the electrolytically polished samples showed the lowest rate of corrosion, chiefly because the surfaces exposed are reduced to a minimum.

It is well known that the progress of corrosion decreases in proportion to the duration of the test, while thermal shock increases scaling, particularly in tests carried out at the highest temperatures and in oxidising gases. In all cases, diffusion towards the surface of the essential elements forming the layer of protective oxides (chromium, aluminium, etc.) leads to lack of these elements in the underlying zones.

(*b*) *Influence of the nature of materials and of chromium content variation in the surface layer:*—Rates of scaling of the different gas-turbine alloys used differ only

* Office National d'Études et de Recherches Aéronautiques.

slightly, because their chromium content is above the minimum which ensures adequate corrosion resistance within the temperature range under consideration. The differences observed are chiefly due to alloying elements, titanium in particular playing an unfavourable part. However, sheets of untreated Nimonic 75 showed abnormal behaviour, with considerably higher scaling rates than samples subjected to prolonged electrolytic polishing. Spectroscopic analysis revealed that this abnormality was due to a considerable chromium loss in the surface layers, arising from hot-rolling, which is generally carried out in air. During this operation, the sheets become covered with a protective layer, in which chromium oxide, formed at the expense of the chromium content of the underlying zones, predominates. Subsequent pickling reveals surfaces deficient in chromium, with lowered corrosion resistance (Fig. 1.).

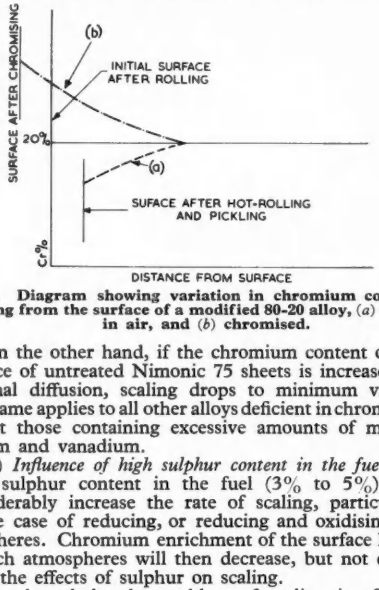


Fig. 1. **Diagram showing variation in chromium content, starting from the surface of a modified 80-20 alloy, (*a*) rolled in air, and (*b*) chromised.**

On the other hand, if the chromium content of the surface of untreated Nimonic 75 sheets is increased by thermal diffusion, scaling drops to minimum values. The same applies to all other alloys deficient in chromium, except those containing excessive amounts of molybdenum and vanadium.

(*c*) *Influence of high sulphur content in the fuel*:—A high sulphur content in the fuel (3% to 5%) may considerably increase the rate of scaling, particularly in the case of reducing, or reducing and oxidising, atmospheres. Chromium enrichment of the surface layers in such atmospheres will then decrease, but not eliminate, the effects of sulphur on scaling.

On the whole, the problem of scaling is of very limited importance, where good quality fuel is used, and in view of this, a further reduction in this type of corrosion would seem to be attainable only through the addition of elements such as zirconium, cerium, and thorium to nickel-based alloys.

(2) Penetration of Corrosion Products

(*a*) *Influence of conditions of corrosion*:—It was noted that corrosion-cracking is propagated chiefly along the

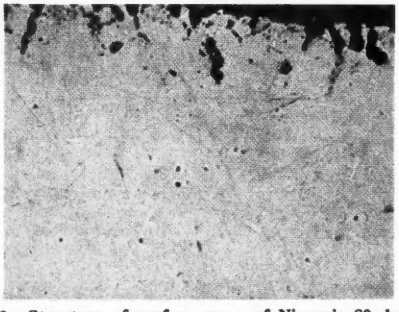


Fig. 2. **Structure of surface zones of Nimonic 80, heated in air for 100 hours at 900° C.** (× 500).

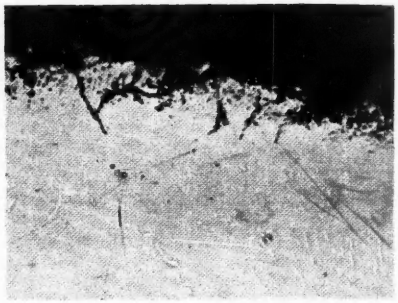


Fig. 3. **Structure of surface zones of Nimonic 80, heated in oxidising gases for 100 hours at 900° C.** (× 500).

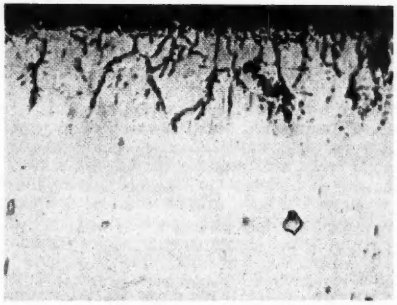


Fig. 4. **Structure of surface of Nimonic 80, heated for 100 hours in pure gasoline combustion gases in a reducing flame at 900° C.** (× 500).

grain boundaries and may completely envelop the surface grains. Penetration depth may be five or six times the thickness of the surface oxide layer. This corrosion appears at temperatures of 700° to 750° C, and increases at higher temperatures. In contrast to scale formation, corrosion cracking is directly linked with the combustion process, particularly insofar as nickel-based alloys are concerned.

Corrosion cracking was observed in corrosion tests with air or oxidising combustion gases (Figs. 2 and 3) but is far more extensive in the presence of reducing compounds (Fig. 4), especially if the fuel contains sulphur, when it takes the form of infiltration in the fluid phase.

It was noted that, in addition to the penetration

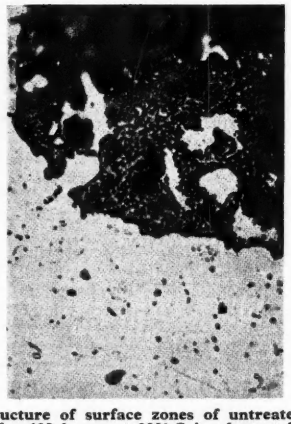


Fig. 5. **Structure of surface zones of untreated Nimonic 75, heated for 100 hours at 900° C in alternately oxidising and reducing kerosene combustion gases.** (× 500).

along the grain boundaries, already mentioned, corrosion frequently sets up a secondary lattice, which is generally less accentuated in electrolytically polished parts.

The " pseudo-oxidising " combustion gases, arising from the dilution of a primary reducing flame with an excess of air, generally exert an action similar to that of gases produced by incomplete combustion. Hence, an excess of secondary air is not sufficient to result in gases which are merely oxidising agents in contact with the turbine blades. Total oxidation of compounds incompletely oxidised during primary combustion is in fact difficult to obtain in a gas turbine, by reason of the high gas velocities involved.

(*b*) *Influence of the type of material and surface chromium content:*—Corrosion cracking was always found to occur, penetration depth varying in each case, but remaining of the same order of magnitude. Contrary to the case with stainless steels, corrosion is increased by high titanium (and aluminium) contents. Cold-working increases the number of corrosion paths, but reduces penetration.

In sheets of 80-20 alloy, surface deficiency leads to considerably increased penetration, particularly if the combustion gases contain sulphur compounds. Fig. 5 shows the surface structure of an untreated Nimonic 75 sheet subjected for 100 hours alternately to oxidising and reducing gases. The considerable amounts of corrosion products completely surround some grains, whose centres are not attacked. Fig. 6, which relates to an electrolytically polished sheet of the same alloy, shows a far smaller penetration of corrosion products.

Fig. 6. **Structure of surface zones of electolytically polished Nimonic 75, heated for 100 hours at 900° C in alternately oxidising and reducing kerosene combustion gases.** (× 500).

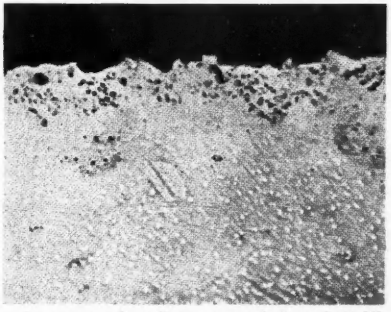


Fig. 7. **Structure of surface zones of chromised Nimonic 75, heated for 100 hours at 900° C in alternately oxidising and reducing kerosene combustion gases.** (× 500).

Fig. 7 shows the surface structure of another Nimonic 75 sheet, the surface of which has been chromium-enriched before testing, with the result that corrosion cracking was completely inhibited. This measure produces the same effect in other materials, as for example, Oneral (Fig. 8).

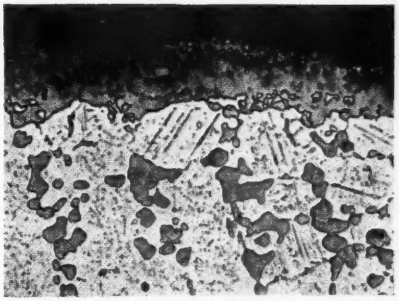


Fig. 8. **Structure of the surface zones of chromised Oneral, heated for 100 hours at 850° C in alternately oxidising and reducing kerosene combustion gases.** (× 500).

(3) Causes and Mechanism of Corrosion Cracking in Refractory Alloys

The overall results of the investigation show that corrosion cracking is due to a deficiency of chromium along the grain boundaries. Hence, an increase in chromium content inhibits such corrosion, while a decrease aggravates it. The mechanism of penetration in different atmospheres would be as follows :—

(*a*) *Penetration of oxidation in air or in oxidising gases:*—As the chromium content is lower along the grain boundaries, oxidation in its initial phase reduces this content below the minimum values for normal protection at test temperatures, thereby causing deep penetration of oxygen.

(*b*) *Penetration of corrosion products in a reducing atmosphere, in the absence of sulphur compounds in the gases:*—Just as chromium inhibits the penetration of oxygen by forming continuous oxide layers, so does it prevent the diffusion of carbon by forming a continuous layer of chromium carbide. Hence, a deficiency of chromium will facilitate the penetration of carbon, while a sufficiency will impede, or even inhibit, such penetration.

(*c*) *Penetration of corrosion products in a reducing atmosphere and in the presence of sulphur compounds:*—Nickel sulphide and eutectics of nickel which are rich in sulphides have a relatively low melting point, while chromium sulphide has a very high melting point (1550° C). Hence, the formation and penetration of sulphur products would be favoured by a local decrease in chromium content, but would be reduced or arrested by adequate enrichment of the surface layers.

Conclusions

The overall results obtained lead to the following conclusions :—

On the whole, scale formation in alloys for gas turbines constitutes a minor problem, while corrosion cracking, which is of fundamental importance, presents a far more complex and difficult problem, because the hardening elements generally used weaken resistance to corrosion cracking.

The extent of corrosion cracking is directly linked with combustion conditions and the distribution of chromium content, chromium being the essential protective element against the various corrosive factors involved ; homogeneity of the material is a vital factor. Perfect combustion reduces to a minimum the effects of corrosion cracking, but is not sufficient to eliminate it.

In practice, solutions must be sought, either in connection with the modification of the material as a whole (increased chromium content), or the surface layers (increase of protective elements in the surface by diffusion), or the provision of metal or ceramic linings for the surfaces in contact with corrosive atmospheres.

U. S. A.

The Correction of Carbide-Tool Troubles

By D. C. KAUFFMAN. (From *The Tool Engineer*, Vol. 33, No. 1, July 1954, pp. 35-42, 13 illustrations.)

Tool control, needed to maintain machine productivity, has many phases. Correction of tool troubles is one of the most important because it is least understood and relies more on experience than on general rules. Correction of tool difficulties often requires trial-and-error checking to eliminate possible causes, until a cure is effected.

EVEN relatively simple machines performing only a few operations can have tooling problems because their productivity has been stepped up substantially. Feeds, speeds, and depths of cuts have been greatly increased in the last few years. Great progress has been made in metal-cutting machine-tool development, but little improvement or progress has been made on the cutting tool.

When a machine is having tool troubles, the first step in the diagnosis is to examine the tool carefully. It should be compared with blueprint specifications, to determine whether it is of the correct material and shape. Such examination may reveal deviations in relief or rake angles, chip-breaker, or other specification.

If the tool is found to conform to specifications, the trouble may be traceable to conditions outside the tool. These might include improper or weakened toolholding devices, worn setscrews, bent or pitted shanks, or even an incorrect previous machining operation Material specifications of the workpiece may have been changed from the time the machine was originally tooled, and the present work may require different feeds and speeds.

Because of the complexity of many machining processes, the investigator of tool troubles is often reluctant to pursue determination of proper feeds and speeds, since this may involve multiple problems. Such machines are usually set for predetermined feeds and speeds before delivery to the plant, so that a major operation may be required to make changes.

When tool troubles are investigated, a pattern of recurring troubles should be sought. It may be that certain operators, batches of work, shifts, or groups of tools may be the cause. If this is indicated, then detection and correction are made easier. Often, several factors contribute simultaneously to faulty operation. To isolate specific causes, only one change at a time should be made.

Once a tool or cutter has been repaired or replaced and is under close observation, the following procedure should be used :—Upon completion of the first pass or cut, or after the first 30 to 60 seconds of operation, the machine should be stopped and the cutting edges of the tool examined with at least an $\times 10$ glass. The edge should be inspected carefully for minute chipping or flaking and evidence of rapid wear. This examination should be repeated many times during the first half-hour of operation. This is one of the best means of isolating the causes of the difficulty and discovering when and where it occurs.

Because of the severe conditions under which carbide tools operate, as well as the nature of the material, they are likely to be subject to more, and a greater variety of, troubles than other tools. The most common troubles occurring with carbide tools are breaking, chipping burning, cratering, rubbing, and excessive wear. Other difficulties often encountered are rough finish on the workpiece and chip clogging.

TOOL BREAKAGE

This is one of the major problems with single-point tools. Faulty brazing and improper tip-pocket design are the major causes. Usually, tools are broken in an area around the cutting point. If the break occurs at a distance from the point equal to the depth of cut, it may be due to excessive wear on the cutting edge from scale, which causes excessive localised heat. Rectangular breaks, with one side at right angles to the side with the cutting edge, are indicative of brazing-strain cracks or cracks from faulty grinding. These cause the tool to give way when it is subjected to cutting pressure. Breaks around the end of the tool or those which cover most of the top of the carbide, but leave a thin surface of carbide, are evidence of brazing strains.

Breakage of the tool may be caused by too small a nose radius, which is likely to burn or fail when subjected to pressure, since it lacks adequate support. The remedy is to use a large radius, to add strength to the cutting edge. Again, the lead angle may be too wide, causing excessive pressure against the tool point, or it may be too small, causing the tool to be weak. If breakage occurs near the cutting point, the rake and relief angles should be reduced. If the break occurs toward the back of the carbide, it may be due to excessive pressure on the tool bit, and increasing rake angles may be in order.

Insert-type toolholders should be used, where practical, because they are stronger and less prone to breakage. Harder grades of carbide can usually be used ; the insert holders are usually made sturdier and of larger cross-sections than brazed tools and, since the carbide inserts are held mechanically, larger pieces of carbide can be employed, so that they are stronger and better able to cope with shock and abuse.

When grinding is suspected as the cause of breaks, the tool should be examined for cracks before and after use. An $\times 30$ microscope is best for this purpose. The reground tools should be checked before use for size, shape, and conformity to blueprint dimensions. Tool-grinding practices should be observed to see if tools are abused during grinding. Improper grinding, as well as poor brazing, can stress carbide tools near their elastic limit. Then, when the tools are put in operation, normal cutting pressures raise the stress above the elastic limit and a broken tool results. Another means of determining if grinding is at fault is to check the performance of reground tools against new tools. Sometimes, in regrinding, excessive amounts of steel are ground away, leaving excessive and unnecessary clearance or tip overhang, tending to weaken the tool.

Too slow a speed or excessive depth of cut will often cause broken tools. Since the depth of cut varies appreciably on workpieces such as forgings and castings, owing to run-out, the sudden shock or vibration resulting may cause tool breakage. Where possible, tools should be designed for added strength by making them larger and heavier, and reducing overhang. The amount of stock being removed by roughing and finishing tools on the same machine should be balanced, so that minimum load is imposed on each tool. Also, it may be possible to add more tools to the operation at the critical position on the machine or at previous machining operations.

Chatter indicates lack of rigidity in the set-up, an obvious cause of tool breakage which is readily corrected. The difficulty may be excessive overhang of the tool. Setscrews should be examined for wear and replaced, if necessary. Centre holes may be improperly located, resulting in run-out, and larger centres and heavier tailstock pressures may be necessary to improve rigidity.

Bent, burred, or dirty toolholders may also cause difficulty. The shank should be flat and properly seated in the toolholder. Hold-down screws should be flat-bottomed and square with the axis of the screw.

Too narrow a chip-breaker may cause excessive

pressure on the tool and be the source of breakage. In this instance a wider and shallower chip-breaker will prevent excessively tight ship curls. Chips should be as open and large as possible, denoting minimum chip deformation, but should be readily disposable.

The shims in brazed tools may be the cause of breakage. Excessively thick shims will mushroom, owing to cutting pressure, deflecting the end of the carbide tip and causing it to break. A thinner shim or none at all should be tried. Shims should be used with hard grades of carbide.

When tools consistently break, a softer or tougher grade of carbide should be tried. Solid carbide tools are stronger than tipped tools and may be tried, where applicable. The difficulty may also be improper or over-hard work materials not in accord with purchase specifications, or workpieces with hard spots and inclusions.

Intermittent splashing of coolant on the hot tool may be the cause of breakage. Chips, fixtures, and tooling in general should be examined, to locate interference with the coolant. It is also possible that the pump is worn or operating improperly, giving low pumping pressure.

A dull tool will cause deflection, either of the tool block, head, or platen to which it is attached, or deflection of the workpiece. Other tools engaged in the workpiece are likely to be broken by the sudden impact or movement as the dull tool engages or leaves the workpiece. Again, machine tools may be underpowered, causing slowing down of the tool or workpiece, and this may also cause breakage.

Tool Chipping

Chipping is a form of breakage often resulting from many of the previously outlined causes. Usually, the cutting edge alone is broken away. Chipping may be in the form of saw teeth or appear like a large wear land. Small cracks sometimes accompany chipping and run at right angles to the cutting edge. Chipping may also be considered as the crumbling or crushing of the cutting edge because of excessive pressure.

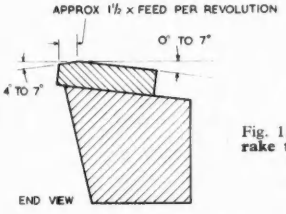


Fig. 1. **Use of negative land rake to prevent chipping of cutting edges.**

The strength of the cutting edge should be increased by reducing the rake angle or dubbing off a narrow land on the rake angle (Fig. 1). A negative rake can be tried, particularly on high surface-speed applications. The finish grinding on the surface of the cutting edge should be improved, to eliminate peaks and valleys which cause the chipping to start. The edges should be blunted lightly by honing at 45 deg. The rougher the cut, the more honing may be required. This is applicable for heavy cast-iron cuts, as well as for steel. Increased speed and reduced feed may also help eliminate chipping. The higher speeds tend to remove metal more easily, by increasing the shear angle, reducing chip welding and pressure against the cutting edge. If chipping persists, the depth of cut may be reduced if it is heavy, or increased if too light. A chamfer, or point angle, instead of a radius on the tool, may also help (Fig. 2).

Eliminating the chip-breaker often stops tool chipping. The small negative land suggested previously may make this possible. Also, increasing the feed rate will cause heavier chips, which may break themselves.

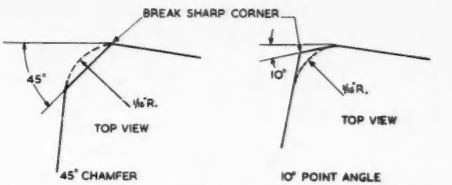


Fig. 2. **Use of chamfer or point angle, instead of radius, to prevent chipping.**

A fillet should be tried in the shoulder of the breaker, or a 45-deg. angle can be used on the back shoulder instead of a right angle. Moreover, if possible, changes in the metallurgical structure of the workpiece may be desirable, to reduce the ductility of the chip, causing it to break more readily. Sometimes, minute nicks or rough edges, due to handling, are the cause. These can be detected by the fingernail or an ×15 lens. To avoid nicks, tools should be coated with plastic and stored individually in compartmented boxes.

Chatter or machine vibration is a major cause of tool chipping. The machine ways may be in poor condition, or improper or insufficient lubrication of the ways may be the cause. All stages of tool-holding or clamping should be examined for cleanliness, warping, and strength.

Tool Burning

Discolouration and smoke accompany cutting action when tools are burned. Such tools are also usually broken down and have sections where the workpieces have smeared the tools. Usually, the red hardness of the carbide has been exceeded and the carbide appears to have washed away. Many forms of tool trouble, such as chatter, chipping, chip clogging, rubbing, and excessive wear, will also cause a tool to burn. It is necessary, therefore, to determine through careful analysis which of the many possible causes are responsible for the burned tool. The various items of design, grinding, feed, speed, depth of cut, set-up, chip-breaker, tool condition, carbide or work material, and coolant should be carefully examined, as previously discussed.

Cratering

Cratering is difficult to control, as it is a common phenomenon when cutting steel and certain allied metals. For best tool life and minimum costs, cratering should take place as far back from the cutting edge as possible.

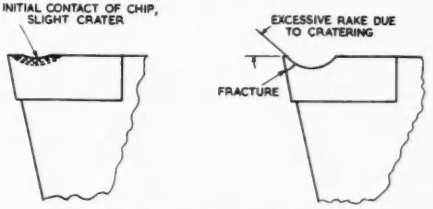


Fig. 3. **Examples of cratering.**

This can be accomplished by changing the design of the tool, according to tests (Fig. 3), and developing optimum feeds and speeds. If excessive cratering persists after an examination of the common causes of tool troubles, the following factors may be applied :—

(1) Use the highest shear angle for minimum chip pressure. This is accomplished by increasing rake; a combination of negative back rake and positive rake may also be used.

(2) Use a grade of carbide which resists chip welding until an extremely high cutting temperature is attained. Certain additives in the carbide matrix, such as titanium carbide, increase its red hardness tem-

perature in the same way that tungsten increases the red hardness temperature of tool steel.

(3) Use the correct feed and speed combination, to reduce chip friction and erosion. Higher speeds will thin the chip and increase its velocity. Less chip area is in contact with the tool and less heat due to friction may result.

(4) Re-design tools so that, if cratering persists, a re-grinding procedure will result in a maximum number of regrinds in tool at a minimum regrinding cost. Single-point tools are usually reground on the end. Up to $\frac{3}{16}$ in. is removed, until all signs of cratering are eliminated. Insert tools can be ground on the top, until a sharp cutting edge is obtained.

Another economical device for designing tools to avoid cratering is to have a 0·10-in. back-rake land of 7 deg. negative and a side rake on the land of 7 deg. positive. When these tools become dull, they can be reground on both the top land and on the front. Experience has shown that such tools can be reground two or three times as much as other tools.

Rough Finish on Workpiece

The rough surface usually consists of minute welded or torn particles due to build-up, galling marks, chatter marks, or lines due to tool marks and other surface defects. This is one of the most difficult tool problems to correct. Consequently, many combinations of factors may be required to eliminate inferior work finishes. Increasing the radius on the tool point will cause cutting lines on the workpiece to overlap. Increasing the rake will facilitate chip removal and prevent build-up. To remove tool marks, reducing the end angle to as low as one degree should help. Increasing the side cutting-edge angle will thin the chips and may help. Reducing the relief angle on the front or side of the tool may also be tried. Negative back rake and positive side rake create a shearing edge which may improve the finish. Mirror-finishing the rake and relief surfaces of the tool may improve the finish on cast iron and non-ferrous materials. This produces a superfine edge and relieves chip pressure against the rake surface. Tool life is usually improved also. This usually applies to precision finishing.

Honing the tool edge slightly, to eliminate ragged edges, will prevent minute chipping of the cutting edge and improve the finish on steel. This also applies in some instances to cast iron.

The use of high surface feeds will increase the shear angle during chip formation as the tool is cutting. In turn, the chip thickness is reduced and pressure against the tool face is reduced, as also is the amount of deformation in the chip. This tends to eliminate build-up on tools and results in excellent finish on the workpiece. A built-up edge not only impedes chip flow, causing rough surfaces, but also reduces tool life. Vibration sometimes builds up in certain geometrical shapes, usually small diameters or disproportionally long pieces. Finish is improved by changing the feed and speed combination causing the condition.

If these suggestions do not improve the finish, other items, such as the rigidity of the set-up, chip-breaker design, tool condition, and grade of carbide, should be checked. In some instances, use of extreme-pressure coolants or other types of coolants may be useful.

Rubbing

Workpiece material may be smeared along the sides or front of the relief or clearance angles of the tool. In some cases the rubbing causes burning, either of the tool or the workpiece, as indicated by discolouration or darkening. The use of excessive clearances or reliefs may weaken the tool by removing necessary support at the cutting edge. This, in turn, may cause burning or chatter. Tools with high reliefs, 12 to 18 deg., have been found, in many instances, to be improved in cutting action and to produce more parts per grind. Accurate size control, however, may be affected. Such high-relief tools may achieve good performance with the addition of low-pressure air-mist cooling.

To prevent the workpiece from slipping in chucks, serrations on chuck jaws should be replaced, resurfaced or reground for a more positive grip of the workpiece. The carbide plating of work-holding jaws or fingers will also contribute to longer life and more positive gripping. In addition to improper chucking pressures, dirt and chips in the chuck may cause difficulty.

Boring tools made by different manufacturers may have different heights from the bottom of the tool to the rake surface. This should be checked. Standard tools are made with wider tolerances than special tools and possibly various angles may be sufficiently off to cause rubbing. Tools finished to smooth mirror finishes will resist smearing or galling on the sides or top of the tools, particularly on forming or grooving tools. When the tool is galled, or the workpiece has poor machinability, too low a feed rate and insufficient depth of cut may cause tools to rub or ride over the workpiece. Increased feed, reduced speed, or increased depth of cut may relieve this condition.

Chip Clogging

The main problem with chip clogging is that it causes excessive down time on production machines. Clogging may also cause broken tools by jamming them against the workpiece or interfering with the cutting action.

Changing the thickness of the chip may relieve some of these problems. A thicker chip may break itself or a thinner chip may be more easily disposed of. Chip thickness may be changed by increasing the lead angle to produce a thinner one, or by reducing the lead angle to secure a thicker one. Changes in the rake angle may also assist in better chip disposal. Sometimes, changing the tool geometry can change the direction of the chip flow to a point where it no longer interferes with the operation of the machine, thus offering a simple solution. The feed, speed, and depth of cut may also be varied to produce the same result.

The common practice of grinding chip-breakers with square-cornered wheels and presenting a square face to the chip is unnecessary. An angle surface and a radius at the back wall of the chip-breaker performs just as well and reduces diamond-wheel wear and the cost of grinding.

Chip-breakers should be designed with maximum width and minimum depth. This type of breaker will reduce cratering and erosion of the tip base and will extend the tool life. Changing the angle of the chip-breaker can also improve its efficiency. Usually, chip-breakers are ground parallel to the lead angle, but a chip-breaker ground at an angle to the lead angle will offer a skewed surface to the chip and may perform better with minimum deflection, friction, deformation, and heat. When establishing a chip-breaker design, the tool should be operated without it for a length of time sufficient to establish a wear pattern on the top of the tool. Chip-flow angle across the top of the tool, distance back of the cutting edge showing maximum impact, and angle of approach should be considered in designing a chip-breaker, to deflect the chip sufficiently to cause it to break without creating excessive deflection.

Sometimes protruding nuts, bolts, shims, tool blocks, holders, coolant pipes, and other protuberances in the vicinity of the cutting tool are the cause of the clogging. Covering such items, so that they no longer interfere with the flow of chips, may solve the problem and reduce down time necessary to remove chips.

If operation is dry, a heavy stream of properly directed coolant may be sufficient to solve the chip-removal problem.

(*Concluded on page* 339)

Cost Accountancy in the Engineering Industry

By S. Howard Withey, F.B.S.C.

PART II

EQUALISING COMBINED CHARGE FOR MAINTENANCE AND DEPRECIATION

Where possible, all items of a capital nature should be collected in the form of monthly or other convenient totals for ledger-posting purposes by using a pattern of purchases book or bought journal ruled by the printer with a sufficient number of columns or sections for the systematic grouping of engineering equipment under definite headings. In this connection, although there is no standard form of ruling in the industry, the following example may be regarded as a good general style, capable of modification to satisfy any special requirement :—

PURCHASES JOURNAL
(" Capital Outlay " Section)

Date	Inv. No.	Name of Supplier	Total Cost	Presses, Pumps, etc.	Grinders and Millers	Boilers, Furnaces	Electrical Gear	Loose Plant

The number of classification columns and their precise headings will naturally vary considerably in individual cases, according to the size of the business and the type of product. The figures representing invoiced capital cost are posted direct from the " Total Cost " column to the credit side of the respective personal accounts kept in the user's purchases or bought ledger, and the monthly or other periodic totals under each heading transferred to the debit side of separate asset accounts opened in the firm's private or impersonal ledger, with dates and brief particulars.

It is always advisable to segregate charges for repairs, cleaning, overhauling, and adjusting of equipment, instead of showing these items in the same accounts as the charges for depreciation. This will greatly facilitate the compilation of annual and cumulative summaries of the cost of operating each unit of equipment and will simplify the maintenance of records giving details of all renovation work.

With the object of lowering upkeep costs, first-class organisations have now been developed, but in order to keep the charges within limits it is wise to exercise a systematic control of the different units and groups of productive equipment. To allow urgent repair work to get out of hand may prove very costly, and a suitable equipment-maintenance system should be instituted by every firm. As far as endurance and reliability are concerned, many machines and units of plant of modern type are extremely economical, but under prevailing conditions the cost of renewals and replacements shows a definite tendency to expand ; in the absence of factual information as to the performance, condition, and running cost of the various sections of equipment, users are compelled to rely largely on estimates whose accuracy it is often difficult to verify.

Engineering-equipment history sheets are sometimes divided into sections to show operation and maintenance cost, classification of spare parts and accessories fitted from time to time, and power and fuel consumption, such data usually being compiled in the costing department. The costs may be sub-divided to indicate the nature and the extent of all the repairs and overhauls carried out during a definite operating period and may be expressed as rates per hour of use. Subsidiary sheets for recording particulars of all foundation and renovation work, time spent, requisitions for components and spares, stores-issue vouchers, departmental reports, etc. provide the information needed to enable the actual cost of maintenance to be readily ascertained ; these sheets are usually certified by departmental managers and passed on for entry on abstracts. Stores ledgers should contain accounts grouped under definite headings, the left-hand side being used for the insertion of quantities and invoiced cost prices of spare parts, accessories, attachments, and fitments received,

EQUIPMENT HISTORY SHEET

Description of Equipment:
Location:
Accessories:
Used for:
Date of Installation: 19
Name of Supplier: *No.:*
Invoiced Cost £ : :
Estimated Service Life: *years*
Annual Rate of Depreciation: %

	Cost 1954	Cost per working hour	Cost 1955	Cost per working hour	Cost 1956	Cost per working hour
Wages :						
Fitters						
Operators						
Materials						
Fuel & Power						
Depreciation						
Servicing						
Provision for Replacement						
Sundries,						
Spare Parts, etc :						
Motors						
Pumps						
Filters						
Rollers						
Switches						
Instruments						
Tools						
Total £						

the right-hand side being used for entering particulars of all issues made from stock and for the value of any returns outwards. Subject to depreciation—to cover which a small percentage may be added to the values as recorded on the credit side of specific accounts—the balances will represent the values of engineering requisites under the different headings, and some firms now rely entirely on the accuracy of such inventory records, the figures being verified at regular intervals. A simple example of an equipment history sheet is reproduced on the preceding page.

In some cases, authorisation for carrying out repairs to equipment is made out on forms by the manager or supervisor, as required, a copy of each form being passed on to the foreman, charge hand, or fitter, to be returned on completion of the job. The specification need not be elaborate ; the essential details to be shown will include a description of the equipment, the number of the job, the starting and finishing dates or times, and the names of the fitters and others engaged on the work. One of the main purposes of these forms is to place on record responsibility for the execution of repairs and renovations.

Forms or sheets used for ascertaining the cost of labour expended on each unit of equipment usually show the number of hours actually worked during the week, a separate section being reserved for arriving at the effective rate per hour worked. Details can then be transferred to an equipment repair labour abstract, summarising the cost under each heading, week by week, and facilitating the preparation of an annual summary showing the total cost and the nature and frequency of the work carried out. If the expenditure on repairs and renewals is large, the maintenance will usually be divided into two main classes, one consisting of daily repairs and adjustments of a relatively trivial nature and the other of the really large jobs. While minor repairs may be much more numerous and often total a very considerable sum, special authorisations are not always needed if personnel are able to deal with the jobs immediately and the cost can be charged against the standing orders ; on the other hand, it is advisable to record the cost of large maintenance work on the debit side of a repairs and renewals account opened in the nominal or expenses ledger, the total sum involved being transferred to the final account at the periodical stocktaking or balancing. The cost of betterments is sometimes debited to the depreciation reserve account, but the aggregate cost of new construction, additions to plant, and foundation expenses should be capitalised by transfers to specific asset accounts.

In cases where maintenance costs are increasing each year, it is advisable to base depreciation computations on diminished book values, in order that the annual decline in the depreciation debit may provide some or all of the margin needed to cover expanding upkeep costs.

For example, for the purpose of reducing costs and speeding up production, the directors of an engineering company recently consulted certain suppliers of equipment in regard to problems of depreciation and maintenance ; by acting on the advice given, they were able to adjust the book values of the productive assets and the company is now in a position to incorporate a uniform figure in each year's engineering costings.

At December 1953, the grinding and milling machines employed by this company had a book value of £15,000, and at a conference it was decided to write down this balance in such a way that at the end of seven years the book value would be reduced to about £7,180, including the capital value of certain fitments. The planning department was instructed to draw up a maintenance budget covering the whole of this period, and this showed progressive increases from £300 in the first year to £1200 in the seventh year, the actual figures being as follows :—

MAINTENANCE BUDGET

Year	£	Year	£
1954	300	1958	960
1955	490	1959	1,085
1956	660	1960	1,200
1957	820		

In January 1954, additional machines were acquired at a total cost of £6,300 including carriage charges, installation expenses, insurance, etc., and it was desired to apply to this capital outlay a method of computing depreciation which would reduce the book value to about £3,510 in seven years. This meant writing off about 52% of the original equipment and about 44% of the value of the new machines ; as it was the intention to include a fixed figure in each year's production costs for the use of the machines, it was clear that the annual rate of depreciation would have to be based on the reduced book values and not on the original cost.

Reference to a specially compiled table showed that in the case of the original machines the appropriate deduction would have to be at the rate of 10%, and that in the case of the new machines the rate of deduction based on diminished value would have to be 8% each year. Consequently, to obtain the desired results, the depreciation computations were made as follows :—

DEPRECIATION COMPUTATIONS

GRINDING AND MILLING MACHINES

	£
1st Year	
10% of £15,000	1,500
8% of £6,300	504
Depreciation	£2,004
2nd Year	
10% of £13,500 (i.e., £15,000 *less* £1,500)	1,350
8% of £5,796 (i.e., £6,300 *less* £504)	464
Depreciation	£1,814
3rd Year	
10% of £12,150 (£13,500 *less* £1,350)	1,215
8% of £5,332 (£5,796 *less* £464)	427
Depreciation	£1,642
4th Year	
10% of £10,935 (£12,150 *less* £1,215)	1,093
8% of £4,905 (£5,332 *less* £427)	392
Depreciation	£1,485
5th Year	
10% of £9,842 (£10,935 *less* £1,093)	984
8% of £4,513 (£4,905 *less* £392)	361
Depreciation	£1,345
6th Year	
10% of £8,858 (£9,842 *less* £984)	886
8% of £4,152 (£4,513 *less* £361)	332
Depreciation	£1,218
7th Year	
10% of £7,972 (£8,858 *less* £886)	797
8% of £3,820 (£4,152 *less* £332)	306
Depreciation	£1,103

By applying this " percentage " method of computation, the total burden of depreciation and maintenance will be equally distributed over the period, as demonstrated in the following table, and a fixed figure of £2,304 will be incorporated in each year's costings :—

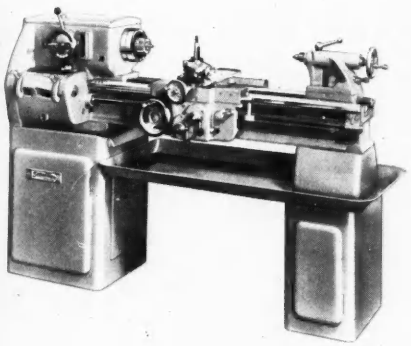
Year	Depreciation	Maintenance	Total
	£	£	£
1954 ..	2,004 ..	300 ..	2,304
1955 ..	1,814 ..	490 ..	2,304
1956 ..	1,642 ..	660 ..	2,302
1957 ..	1,485 ..	820 ..	2,305
1958 ..	1,345 ..	960 ..	2,305
1959 ..	1,218 ..	1,085 ..	2,303
1960 ..	1,103 ..	1,200 ..	2,303
Totals	£10,611	£5,515	£16,126

(*To be continued*)

New Materials, Processes and Equipment

GEARED-HEAD PRECISION LATHE

The new Sebastian 13-in. geared-head lathe, manufactured by Sheldon Machine Co., of Chicago, is an all-purpose precision lathe, rigidly built and combining power with extreme accuracy. The lathe features a multiple-splined spindle which is thick-walled, hardened, and ground. The spindle is supported by " zero-precision " tapered roller bearings for long-life accuracy. The long tapered-key drive-spindle nose is standard on this lathe. All gears in the headstock run in oil, are extra wide, and are designed for quiet, efficient operation. The enclosed gear box is large and has 60 different pitches and feeds. A lead-screw reverse lever is incorporated in the gear box, and is easily accessible to the operator.



A cam-action tailstock clamp permits rapid shifting of the tailstock. The carriage is massive, and has an extremely large bearing surface. A built-in one-shot oiling system provides lubrication for all bearing surfaces. Two friction-disc-type clutches in the large apron provide power for longitudinal and power cross-feed. These clutches can be engaged individually or simultaneously. There is a neat cabinet in the pedestal leg for convenient storage of tools and accessories. The bed is a heavy, one-piece casting with extra large bearing surfaces on the ways. The total weight of the machine exceeds 1600 lb.

AUTOMATIC 18-STATION DRILLING MACHINE

The use of multiple-station, electrically controlled, automatic machines, which increase the rate of output of engines and parts and reduce the unit cost of items, has revolutionised American automobile-manufacturing methods. The new system is used, among many purposes, for machining rough engine-block castings and forgings for engines and drive mechanisms.

An example of such equipment is the automatic 18-station machine illustrated, which drills all holes in the converter reaction flanges of the " Dynaflow " drive of Buick cars at the Buick division of the General Motors Corporation. The machine was built by the Kingsbury Machine Tool Corporation of Keene, New Hampshire, who estimate that its production capacity is 254 drilled flanges per hour.

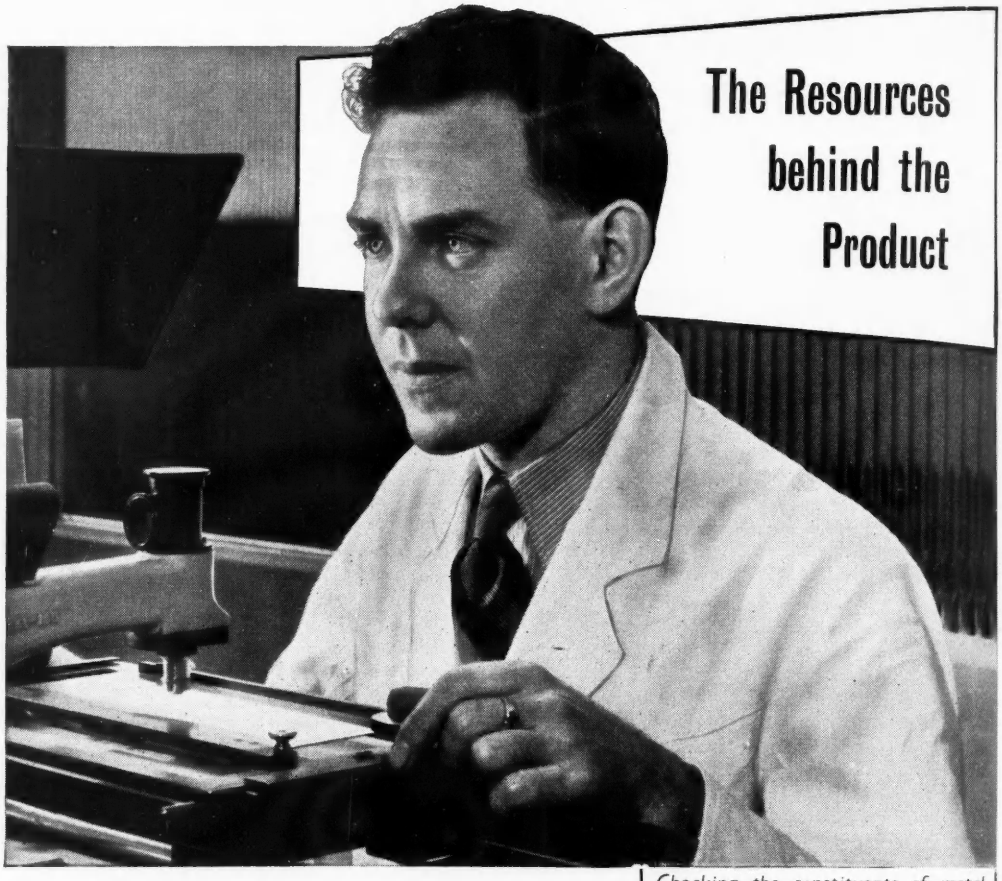
This drilling and tapping machine is basically a Kingsbury standard central-column, 18-station, automatic machine, with a horizontal indexing dial, 60 in. in diameter, which rotates clockwise. Designed for one-man operation, it is equipped with all control devices, including electric selective trips and safety circuits. There are seventeen drill heads and one tapping unit, all mounted radially to the central column on block supports and connected with electric circuits.

Nine identical fixtures on the rotary dial are used for locating the workpieces, by their central hole, on a horizontal plug, so that the finished face of each reaction flange is vertical and the rear face is clamped back against a hardened steel locator, with the long straight edge of the work held at an angle by a steel block.

The flanges to be drilled are so large that it was not possible to mount on the dial as many holding fixtures as there are operations to be performed, so that only the nine fixtures were provided. Consequently, indexing is effected in two stages. At the first index, the workpieces in the fixtures are aligned with approximately half of the drill heads, and at the next index the remaining units are aligned with nine other drill heads. Thus, two indexes and two drill-head cycles are needed to complete the operations on one workpiece. 1·3 seconds are required for the first index and 6 seconds for the drill head carrying out the longest operation to complete its cycle ; in the second stage, 1·3 seconds are also required for the index and 5·4 seconds for the cycle of the heads drilling the longest holes, making a total of 14 seconds to complete work on each piece.

The sequence of procedure is as follows :—The operator loads the first fixture and it is indexed automatically. Two indexes later, another fixture comes into position and is loaded. When all fixtures on the dial have been loaded, the operator removes one reaction flange which has been finished and puts another into a fixture for each two indexes of the dial. Clamps, which hold the work against the locators, are operated manually and swing clear as they are unclamped for removal of the drilled and tapped reaction flanges.

The drill heads at most stations are mounted on their blocks at a slight angle, and one is horizontal. Two vertical heads are mounted on the central column of the machine. A terminal box on each drill-head support block and one for the machine facilitate servicing of the electrical circuits and simplify removal of the support blocks. All electric controls are located in a separate cabinet attached to the machine.



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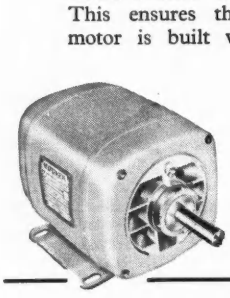

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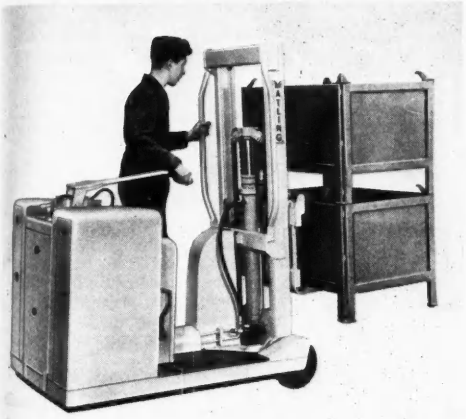
Tripping is effected automatically by cam-operated switches. A cam on each locating fixture trips a micro-switch on the central column only when the proper drill heads are in correct alignment with the fixtures. There are two separate tripping circuits—one for tripping all those drill heads which operate after the first index, and the other for those heads which commence drilling after the second index. Each circuit is controlled in turn by the micro-switches.

This machine actually sets the pace for the operator, because it performs all necessary operations on the reaction flanges with only one chucking and one handling of each flange, indexing and tripping of the drill heads being carried out automatically by the dial index.

BATTERY-OPERATED FORK-LIFT TRUCK

An entirely new model of fork-lift truck, designed to meet most current mechanical-handling requirements, and which can be operated either as a ride-on or pedestrian-controlled unit, is announced by Matling Limited, of Fallings Park, Wolverhampton.



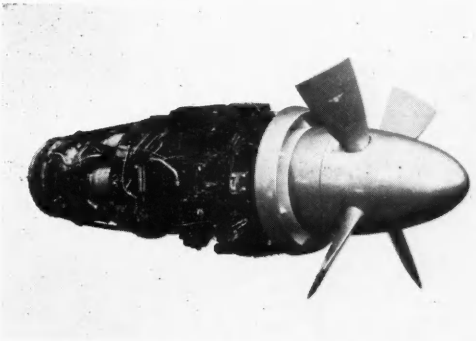
The new truck, which was demonstrated for the first time at the Mechanical Handling Exhibition at Olympia, is battery-operated, and has a capacity of 2000 lb. It is being produced as a single-mast model and also with a telescopic lift, so as to be able to clear doorways and other overhead obstructions, and, at the same time, to permit stacking to maximum height in storage areas.

PROPELLER-TURBINE AERO-ENGINE

The Napier " Eland," manufactured by D. Napier & Son Ltd., of Acton, London, W.3, is a single-shaft propeller-turbine aero-engine which develops 3000 ehp for a net dry weight of 1575 lb. Of conventional layout and mechanically simple in design, the " Eland " incorporates many features which have enabled engine weight to be kept to a minimum and which have resulted in an extremely clean overall shape, with a total frontal area of only 7·1 sq ft. Economic fuel consumption, together with low specific weight, makes the engine suitable for both civil and military applications.

In the mechanical design of the engine, particular attention has been given to the requirements of servicing and overhaul. The engine is divided into four major assemblies, comprising reduction gear, compressor, combustion system, and turbine, respectively. Each major assemly can be replaced individually so that, for example, when the turbine is removed, the reduction gear, the compressor, and the combustion system need not be disturbed. The combustion chambers and burners are separately removable *in situ*, for inspection, etc., and free access is available to all engine accessories.

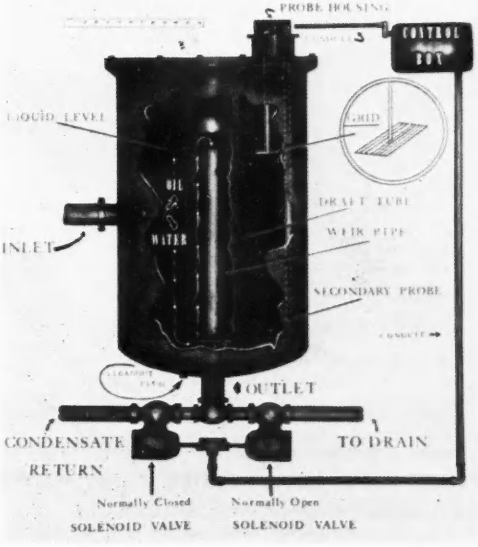
As a result of an intensive programme of research on axial compressors carried out over a number of years, the characteristics of the compressor are such that the margin between surge and the economic operating line gives the engine excellent handling qualities. Full advantage of compressor characteristics has been taken in the design of the controls, and the engine has a rapid surge-free acceleration. The control system also embodies devices giving instantaneous protection in emergencies.

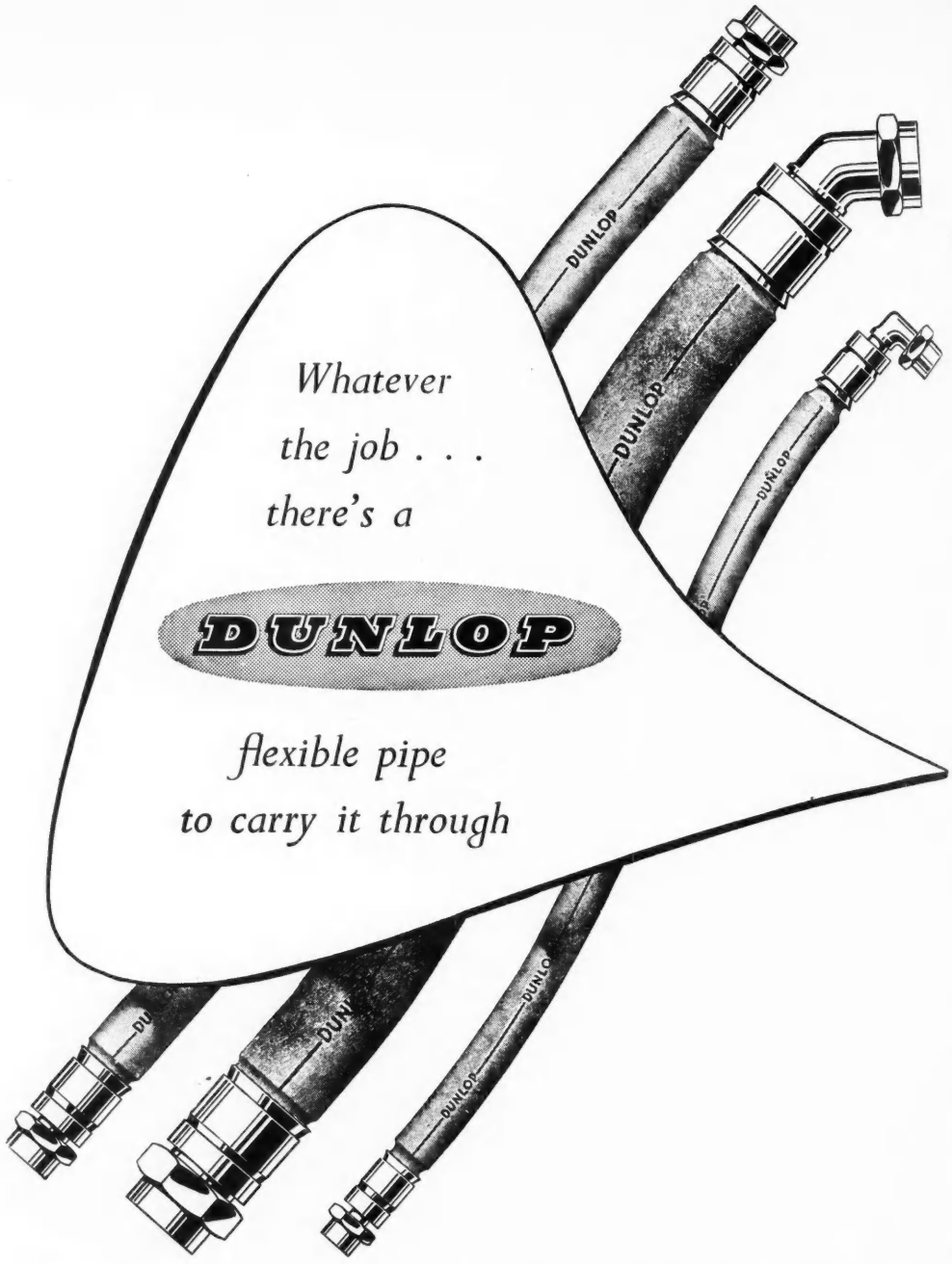


Although these outstanding features enable the " Eland " to offer great economies in conventional applications, the engine is capable of considerable development and is sufficiently versatile to be utilised for other special purposes, such as the Fairey " Rotodyne."

OIL-SLICK SEPARATOR AND DETECTOR

Available in three standardised styles for all sizes of boiler installations, the oil-slick separators and detectors manufactured by the Techniflex Corporation, of Port Jervis, New York, consist of a settling chamber-type separator incorporating an automatic oil-slick detection probe system and a control box which converts the probe-detection signal into control and alarm responses. The separator is divided by a draft-tube into an outer or annular settling chamber, where any pos-





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sible slick collects at the surface, and an inner chamber from which oil-free water is returned to the condensate return system. The probe-detection system is contained in the outer chamber. A thin slick layer at the surface of the liquid in the outer chamber produces an electrical unbalance between the two probes. This results from a partial screening, of the grid-probe by a film or slick of oil As soon as this unbalance occurs, it is communicated to the control box. In all three styles of the slick separator and detection systems, the control box then automatically discontinues the normal condensate return flow, and institutes a diversion of the effluent to waste.

In the style " A " system (illustrated), which demands supervised purging of the system to cleanse it of oil, a two-valve nest controls the direction in which the effluent is sent. Styles " B " and " C " on the other hand, provide for an automatic purging and an automatic resumption of normal condensate return. In accomplishing this automatic purging action, style " B," like style " A," employs a two-valve control nest, whereas style " C " uses a single-valve control system. Styles " A " and " B " are adapted to vacuum, atmospheric, and pressure-type condensate systems, while style " B " is normally suitable for atmospheric service only.

All systems incorporate a " fail-safe " control action on power failure, and all provide for visual and audible alarms after slick detection.

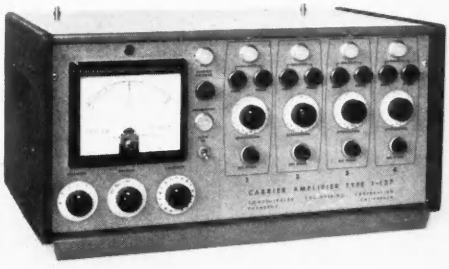
QUICK-DRYING LACQUER FOR HIGH-IMPACT POLYSTYRENE

Permanent adhesion to high-impact polystyrene is stated to be accomplished by " Rez-N-Lac 475," a new quick-drying lacquer announced by the Schwartz Chemical Co., Inc., of New York. The lacquer, which was formulated specifically for decorating high-impact polystyrene, to which most lacquers have poor adhesion, is said to contain a substance which alters the polarity of the polystyrene surface so that maximum adhesion is assured. Drying time ranges from one to five minutes, depending on whether air-dry or force-dry methods are used.

Because the base resin used in the lacquer is non-toxic, it is claimed that it may safely be used on children's toys, dishes, and food containers, and on products which may come in contact with the body. In addition to being water-proof, the lacquer is unaffected by soaps, oils, fats, or alkalis, and can be applied by brush or spray. It is available in clear, as well as in a wide range of transparent and opaque, colours, and is packed in one and five-gallon cans, and in 55-gallon steel drums.

4-CHANNEL CARRIER AMPLIFIER

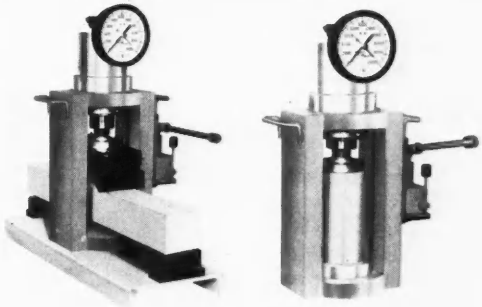
A 4-channel carrier amplifier, with a flat frequency response from zero to 3000 cycles, has recently been introduced by Consolidated Engineering Corporation, of Pasadena, California. This new Type 1-127 Amplifier has a frequency range three times that available in any similar instrument. Industries, especially in the aircraft, guided-missile, and atomic-energy fields, should find the amplifier system particularly useful for reproducing outputs of resistance- or reluctance-type transducers in the frequency range mentioned.



The instrument contains a regulated power supply, a 20-kc oscillator, 4-carrier amplifiers with associated bridge balancing and demodulator circuits, a control and metering system, and a calibrating system. For nominal amplifier sensitivity, a one-millivolt modulation signal causes full-scale output of $\pm$ 50 mA. The amplifier is provided with a gain control, to adjust for full scale when an input of one millivolt is applied with any source impedance from 60 to 1000 ohms. Amplifier accuracy is $\pm$ 1% for modulating frequencies from zero to 3000 cycles. The instrument will operate on line frequencies of 50, 60, and 400 cycles, and voltages of 105-125 a.c. Ambient temperature range is from — 20° to 50° C.

PORTABLE CONCRETE-TESTING MACHINE

A new portable machine announced by Soiltest, Inc., of Chicago, Illinois, makes possible rapid testing in the field of concrete and similar materials with laboratory accuracy. This 200,000-lb capacity machine can be used for testing concrete cylinders and beams and other construction materials. The tester is entirely self-contained and no electrical or pressure connectors are required. Loads are developed by means of a hand-operated, two-speed concentric pump, which actuates the piston of the main hydraulic system. The machine, which is simple to operate, is equipped with a large direct-reading gauge and a maximum-load pointer. Standard 6-in. diameter concrete cylinders, 12 inches in height, are accommodated in the normal set-up. Variations in specimen height are easily compensated, by adjusting the upper platen to position.

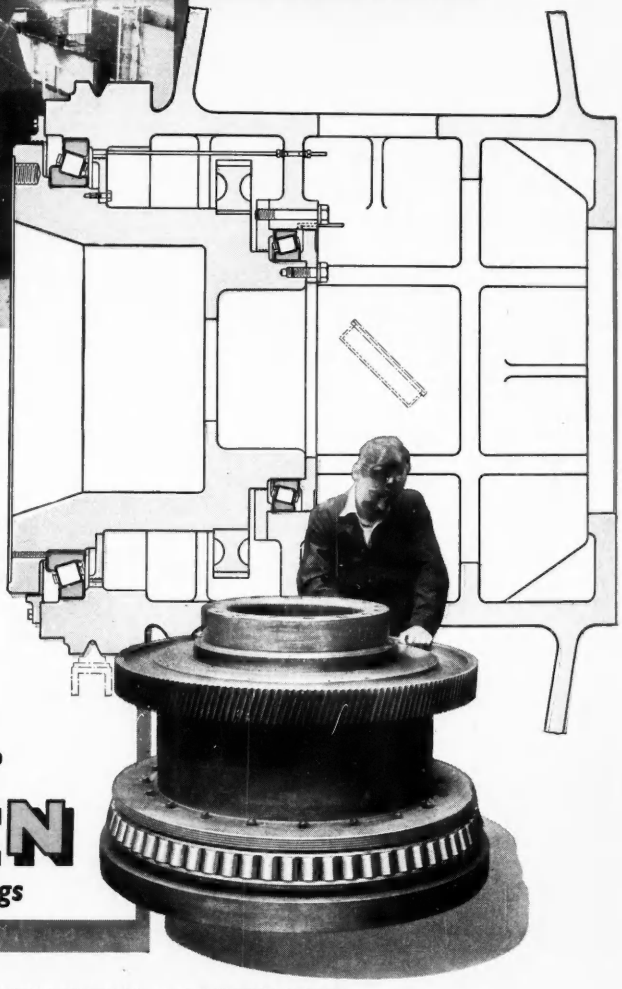


The machine can be rapidly converted to a 20,000-lb capacity flexure-testing machine for beam tests. The flexure attachment includes transverse beam-loading apparatus and a large-diameter 20,000-lb capacity direct-reading gauge. Beams up to 42 in. in length can be tested and either centre or third-point loading can be used.

Use of this equipment is not confined to concrete testing. It can be used as a high-capacity shop or laboratory press ; as a compression-testing machine for castings or small vessels ; as an experimental press for powdered-metals work ; and as a laboratory testing machine, for all types of routine work on small-sized specimens, such as ceramic pieces, rock cores, timber, and welded sections.

The illustration shows (right) the standard machine and (left) its conversion for beam tests.

ON THE GRUBB PARSONS 74" TELESCOPE



The illustration shows the Grubb Parsons 74" telescope, at the Festival of Britain. For the movement about the Declination axis the bearing requirements were for maximum rigidity, a high degree of accuracy and minimum frictional loss. The trunnion was accordingly mounted upon Timken tapered-roller bearings, one of 37" bore, the other of 22" bore.

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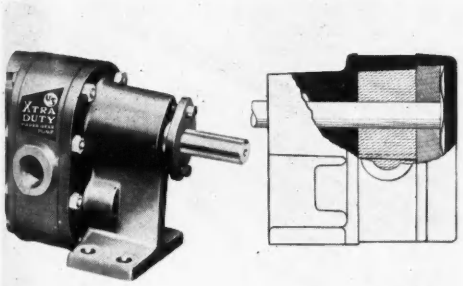
HEAVY-DUTY TAPERED-GEAR PUMP

Especially designed for difficult service applications a tapered-gear pump has recently been introduced by The East Shore Machine Products Company, of Cleveland, Ohio. Developed to handle liquids containing materials of an abrasive nature or foreign matter which normally punishes a gear pump severely, the new model, designated U-3, should outlast a conventional pump many times in any tough application. Moreover, it will maintain its high initial mechanical and volumetric efficiency throughout its service life. By reason of its special taper design, any wear occurring is automatically taken up without effect on clearances.



The impeller gears, though of the straight spur type, are ground with a 2-deg. taper after hardening, to match the tapered recess in the housing. As wear occurs, spring tension on a floating back-up plate acts to force the gears into the taper bore of the case, maintaining close fit and constant high vacuum. Indicative of the high efficiency of the unit is the 29-in. vacuum level it attains under conditions of restricted flow.

With a nominal capacity of 8 USgpm, the pump will deliver up to 18 gpm at 1000 rpm shaft speed, at pressures ranging up to 250 psi. Construction details of the new U-3 pump are especially suitable for heavy-duty service. Shafts are hardened and ground, and the unit is equipped with generously dimensioned bronze bearings.

PRODUCTION GAUGING INSTRUMENT

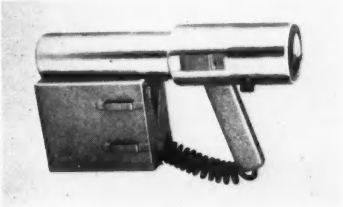
A production gauging instrument which inspects four dimensions simultaneously on the carrier body of an automatic transmission is manufactured by The Sheffield Corporation, of Dayton, Ohio. In one quick operation, an unskilled operator can check the seat chamfer on the inside of the body, outside body diameter, overall body length, and the dimensions from the top of the shank to the bottom edge of the upper flange.

Dimensional quality of the part is indicated by a master light and four individual signal lights on the diagram panel. When all of the dimensions are within tolerance, the master light remains white and the four signal lights on the panel black out. However, if any of the dimensions are out of tolerance, the master light turns red and the signal lights indicate the faulty dimensions by turning either red or green, indicating respectively undersize or oversize, while the lights of the correct dimensions black out.

The instrument is equipped with three new small " Electrichek " gauge heads for checking outside dimensions. An " Airlectric " gauge head checks the internal seat chamfer, transferring the variations in air flow to an electric circuit which operates the red, green, or blacked-out signal light

PORTABLE, BATTERY-OPERATED SCINTILLATION COUNTER

The " PRI Scintillator," manufactured by The Radiac Company, Inc., of New York, is a portable, battery-operated scintillation counter which is one-hundred times as sensitive to gamma radiation as the most sensitive Geiger counter. It is suitable for conducting aerial prospecting surveys for uranium and oil, as well as for prospecting on foot or from a moving vehicle. It may also be used for health-physics laboratory surveys. The instrument is as simple to operate as a Geiger counter and can be used by a relatively untrained person.



The ranges of the " Scintillator " are 0·025, 0·05, 0·25, 1, 5, and 25 mr/hr, and include a zero adjustment. It employs a sodium-iodide crystal, optically coupled to a photomultiplier tube. The circuit operates from —25° C to 40° C, and is independent of altitude to heights over 15,000 feet. No external calibrating control is needed. The photomultiplier tube and crystal are shock-mounted. Power is supplied by low-voltage batteries in a separate container, which can be attached to the operator's belt. The probe, which is immersion-proof and tropicalised, is detachable.

The instrument is supplied complete with batteries, tubes, shoulder strap, calibrated radioactive sample, and complete instructions.

COMBINATION COLORIMETER AND SPECTROPHOTOMETER

A combination colorimeter and spectrophotometer which produces high wavelength accuracy and spectral purity through the use of a diffraction grating is announced by the Bausch & Lomb Optical Co., of Rochester, N.Y. Called the " Spectronic 20 " because of its 20-mμ band pass, the instrument is designed for speedy, simple operation by laboratory technicians who require the use of only two control knobs in making routine colorimetric analyses.

The instrument analyses any liquids or solids which transmit light, by subjecting a sample to light of specified wavelengths. The degree of light transmittance is registered on a double scale, where readings may be taken in terms of either transmittance or optical density.

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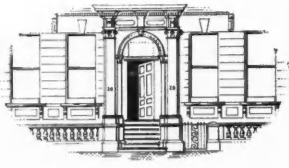

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The operator can adjust the diffraction grating for any wavelength in the entire range of the instrument by turning a control knob, without being limited to available filters. Effective range is stated to be from 375 mμ (near ultra-voilet) to 950 mμ (near infrared). For the range from 650 mμ to 950 mμ, an infrared tube and filter are quickly substituted for the standard tube.

As a colorimeter, the instrument makes possible quick routine tests by subjecting the sample to fixed wavelenth settings. Resulting readings can be readily interpreted as concentration values, from predetermined calibrations supplied with the instrument.

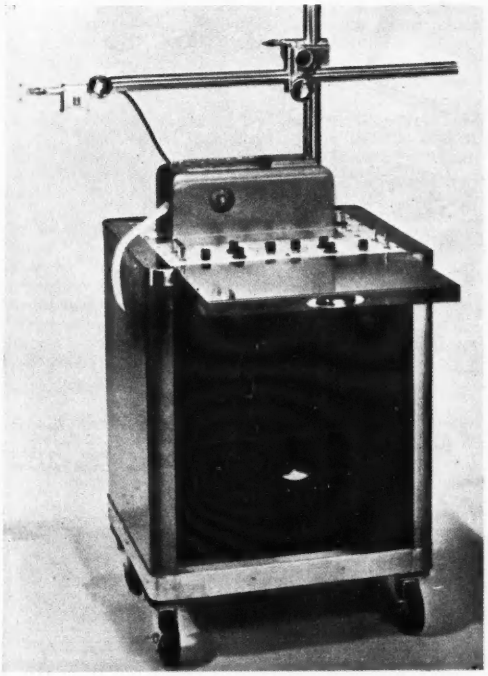
More intensive study is possible by using the instrument as a spectrophotometer. Here, the sample is subjected to light of the desired wavelengths, to obtain transmittance and density readings for interpretative analysis and the construction of transmission and/or absorption curves.

Basic components are a built-in grating monochromator, a photo-emissive detector to pick up the light which passes through the sample and transmit it in the form of photo-electric current, and a printed-circuit electronic amplifying system to build up the current so that it will register on the scale.

TENSION ANALYSER

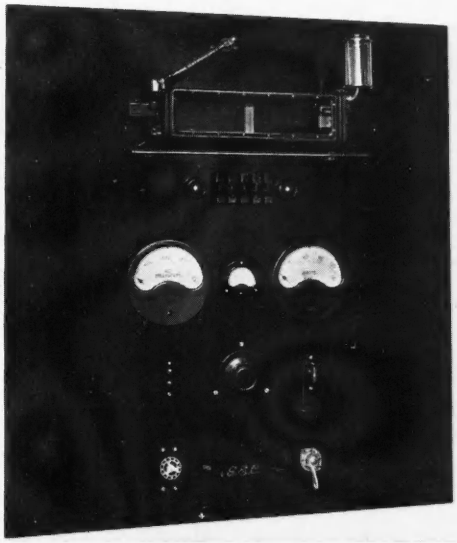
A new tension analyser for accurately measuring and recording instantaneous tension loads in filamentary materials is announced by Brush Electronics Company, of Cleveland, Ohio. This complete unit is equally applicable to all textiles and to fine wire of reasonable flexibility, and will measure both static tension levels and dynamic tension variations while the material is running at high production speeds.

In operation, the filamentary material, the tension of which is to be measured, is placed over the three pulleys of the transducer. The tension in the material causes mechanical displacement of the centre pulley. These displacements, both static and dynamic, are converted into electrical signals, which are amplified and recorded on a direct-writing oscillograph. Special fittings have been designed, so that the transducer may be positioned an any plane at any reasonable level.



INSTRUMENT FOR MEASURING THE QUALITY OF A CARBURISING ATMOSPHERE

A new instrument for measuring the quality of a carburising atmosphere has been developed by The General Electric Company Ltd., of London, W.C.2. It consists essentially of a compartment (with a transparent front), inside which is an iron wire which is carburised in the atmosphere under test and cooled rapidly, so that it is transformed to martensite. In this condition, the electrical resistance of the wire is a measure of its carbon content and hence of the carburising potential of the atmosphere. Values of the electrical resistance of the quenched wire can be directly related to carburising potential from a calibration curve. Operation of the gauge is straightforward and one measurement takes about 15 minutes.



The carburising potential measured on the G.E.C. carbon gauge is the carbon content of a steel with which the atmosphere would be in equilibrium at a given temperature. For example, if the carburising potential of an atmosphere is measured on the gauge as 0·65% C, then this atmosphere would be neutral to a 0·65% C-steel at the same temperature. This method of evaluating the quality of a controlled atmosphere is particularly useful in such processes as the hardening of medium- or high-carbon steel where decarburisation is to be avoided, the restoration of carbon to surfaces of parts which have been decarburised during casting or heat treatment, and the carburisation of steel to some specific value of carbon content.

A panel-mounted carbon gauge is illustrated but, where the instrument is required for use on several furnaces, it can be supplied as a portable unit. The gauge wire runs through a compartment at the top of the panel. The carburising gas passes through this compartment and is burned as it emerges from a nozzle on the right. Heating current through the wire is adjusted by a variac. For measuring the resistance of the gauge wire after carburising, the voltage developed across it is measured for a small known value of current. The carburising potential of the gas can then be read off from the calibration chart.

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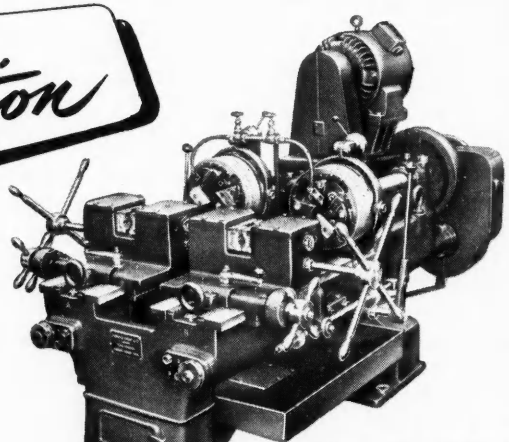

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CLASSIFIED ABSTRACTS

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BRAKES AND CLUTCHES

Measurement of Brake-Drum Temperature.

By E. J. MARTIN and J. E. WILSON. (From *Automotive Industries, U.S.A.*, Vol. 110, No. 12, June 15, 1954, pp. 34-37, 93, 9 illustrations.)

BRAKE-DRUM temperature measurement has long been a controversial subject. One reason for this has been the inability to measure accurately the surface temperature at the point where rubbing takes place and where the heat is generated. When using a thermocouple for brake-temperature measurements, it is common practice to percussion-weld a thermocouple to the flat bottom of a hole which stops about 0·03 in. from the rubbing surface, and to use a potentiometer to measure the thermocouple output directly in °F. However, by this method, only the general temperature of the brake-drum section is measured.

This article describes results obtained with a radiation pyrometer, designed around a thermopile which intercepts a small fraction of the radiation from the brake drum and converts this energy into a measurable electrical signal. By directing the pyrometer at a spot on the drum surface following the brake shoe, the surface temperatures generated at the rubbing surface can be measured with considerable accuracy.

The highest surface temperature measured with the pyrometer during various tests was about 1400° F, corresponding to the maximum deflection on the pyrometer temperature-recording instrument. One limitation to the use of the pyrometer for surface-temperature measurements was the change in the surface characteristics. Where surface temperature did not exceed 800 to 1000° F, the brake-drum surface remained shiny and clean. Higher temperatures, however, caused the surface to become blackened and, as the pyrometer calibration changed when the surface became darker, the pyrometer output had to be interpreted by means of a calibration curve corresponding to the type of surface.

Several locations of the pyrometer, relative to the brake shoe, were tried out, and the most successful was found to be in the centre and at the trailing end of the forward brake shoe. After completing these tests, questions arose as to the rate of cooling of the brake-drum surface. To determine this rate, a series of stops under constant test conditions was made, and the distance from the forward brake shoe to the pyrometer was varied through a range of $\frac{1}{8}$ to $1\frac{1}{4}$ in.

ELECTRONICS

The "Metrechon"—A Halftone-Picture Storage Tube.

By L. PENSAK. (From *RCA Review, U.S.A.*, Vol. 15, No. 2, June 1954, pp. 145-162, 9 illustrations.)

ALL known storage tubes depend on the storage of electric charges on insulators. The differences between the various tubes arise from the manner in which (a) the charges are put onto the insulator (the writing operation), (b) the charges produce an output signal (the reading operation), and (c) the charges are removed (the erasing operation) to clear the insulator for further writing. Writing is accomplished by bombardment, the charge pattern resulting either from secondary emission effects or from bombardment-induced conductivity. Reading and erasure are commonly combined, so that removal of the charges also produces an output signal. More than one copy of the stored signal can be obtained when the reading beam is made small enough to remove only part of the stored charge on each scan. However, any change of stored charge varies the output-signal level of the succeeding copies. This deterioration of the output signal can be prevented by separating the reading and erasing operations.

Such separation can occur when the reading beam is unable to land on the stored charges, but can be modulated by them in a kind of grid control action. Erasure can be accomplished by the writing beam or by the use of a third beam. A tube which operates in this manner can produce signals from its stored charges without disturbing them, and therefore produces multiple identical copies. This is the basic principle of the "Metrechon" tube described in this article.

With regard to possible applications of this tube, it could, with some modification, including the use of electrostatic deflection plates, prove useful for the storage of fast single transients. The tube may also have a use in nuclear physics for storing pulses occurring at too great a rate for conventional equipment to handle, and then counting and analysing the reading output at more practical rates. The pulses can be applied to the grid of the writing gun to produce up to 10 million pulses per second, or more, if necessary. The writing beam can be scanned in a rectangular raster, to spread the spots of charge over the target for the duration of one "frame", which can be chosen to allow 10,000 or more spots to be stored. A reading system can then be designed to count and measure the magnitude of the stored charges at slower rates. There are undoubtedly problems which must be solved before such a system can be practical, but it seems that it might be a valuable tool for research work.

Another application might be the storage of one frame of a television picture created, for example, by an industrial television system and used to catch an event occurring only intermittently. The tube has been tested for this purpose and, while it necessarily causes some deterioration of the picture quality, it works fairly well.

Many other applications for the tube will be considered and tried as its properties become known to those with special problems.

The Photoconductive Cell.

By J. E. JACOBS. (From *General Electric Review, U.S.A.*, Vol. 57, No. 4, July 1954, pp. 28-31, 5 illustrations.)

ONE of the most promising mass-application products of solid-state physics research is the photoconductive cell, which differs from the more familiar photoelectric cell in many respects. The simple photoelectric cell is a high-vacuum electron-emitting device which is relatively insensitive to feeble radiations of light. The photoconductive cell is classed as a semi-conductor, because its operation depends not on electronic emission in a vacuum but on electronic conduction in a field. The resistance of a photoconductive cell is a function of the intensity and the wavelength of radiation falling upon a radiation-sensitive crystal within it. Thus, the cell has its highest resistance when no radiation falls

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upon it and a diminishing resistance as radiation increases.

Of all the materials exhibiting photoconductive properties, cadmium sulphide (CdS) and cadmium selenide (CdSe) appear best suited for general applications, though both differ greatly in their sensitivities and time constants. The advantage possessed by both these materials is that there is a great difference between the resistance of an unirradiated crystal, called its dark resistance, and its resistance when subjected to radiation. Thus, for example, the dark resistance of a CdS crystal is from 10,000 to 100,000 times greater than its resistance when irradiated with 100 foot-candles of light. The contrast is even greater for a CdSe crystal under the same conditions of irradiation, as its dark resistance is from one-million to ten-million times greater. With either CdS or CdSe cells, this wide range of resistances can be covered in continuous steps, by varying the irradiation from total darkness to 100 foot-candles.

The sensitivities of CdSe cells, measured under tungsten-lamp radiation, is of the order of 1·0A per lumen, with an applied d.c. voltage of 100V. CdS cells will exceed this amperage by factors as high as 50. Dark resistances of either cell are in excess of 5000 megohms. Consequently, when illumination levels are of the order of millilumens, these cells possess an extremely good signal-to-noise ratio.

Because of the high radiation absorption of CdSe, it is necessary to increase the working area of the material, to achieve the maximum ratio of light to dark current. This is effected by making the cell as thin as possible, thus permitting a maximum current of 0·01 mA. CdS cells, on the other hand, handle currents up to 1·0 mA and, when backed up by a copper plate, can be used at a power dissipation of 250 mW.

In growing photoconductive crystals and subsequently processing them into cells, the choice must always be made between high sensitivity with slow response, and rapid response with relatively low sensitivity. Fortunately, the photoconductive cell retains the desirable features of both high-speed response and large current sensitivity when it is coupled to a transistor, preferably of the grounded emitter type. In this arrangement, the properties of both the cell and the amplifier are utilised as fully as possible. For example, a photoconductive cell now available, used in conjunction with a single-junction type of transistor, will operate a conventional d.c. relay at a rate exceeding several hundred operations per second, with incident light levels of the order of a few foot-candles. This device is extremely simple, consisting only of the cell, the transistor, and a relay, connected to a suitable d.c. supply.

FLOW MECHANICS

Approximate Solution of Laminar Boundary-Layer Equations.

By I. TANI. (From *Journal of the Aeronautical Sciences*, *U.S.A.*, Vol. 21, No. 7, July 1954, pp. 487-495, 6 illustrations.)

IT has been shown by Stewartson that the momentum equation for a compressible laminar boundary layer is transformed into that for an incompressible laminar boundary layer, assuming that the Prandtl number is unity, and that the viscosity is proportional to the absolute temperature. If any one of the assumptions is dropped, the transformed equation is no longer of the same form as that for an incompressible flow, but it is still easy to solve, because of the disappearance of variable density. Consequently, it seems adequate to consider first the laminar boundary layer in incompressible fluids.

The most frequently used method of solving the boundary-layer equations approximately is the momentum-integral method, in which the momentum equation is integrated over the boundary-layer thickness, and is hence satisfied only in average. By assuming a definite form for the velocity profile as a function of the normal distance, an ordinary differential equation is obtained, with the distance along the wall as the independent variable.

In this paper, a simple method is developed for solving approximately the equations of the laminar boundary layer. The velocity profile is assumed as a member of a one-parameter family of curves, the parameter being different from the usual Pohlhausen parameter. The Pohlhausen parameter is calculated by a simple quadrature formula, which is derived from the energy-integral relation. The relation between the profile parameter and Pohlhausen parameter is determined from the combination of both momentum-integral and energy-integral relations. The accuracy of the method is examined by comparing the results with those of exact solutions for the flow of incompressible fluid. Satisfactory agreement is obtained. The method of solution is then extended to the flow of compressible fluid along a heat-insulated wall, assuming the Prandtl number slightly different from unity and the Sutherland formula for the variation of viscosity with temperature. As an example of the application, the effect of compressibility on separation point is discussed.

A Correlation of the Resistance to Air Flow of Wire Gauzes.

By P. GROOTENHUIS. (From an advance copy of a paper submitted to *The Institute of Mechanical Engineers*, *London*, July 1954, 8 pages, 6 illustrations.)

SINGLE screens or wire gauzes are used for controlling the flow in wind tunnels and other duct systems conveying gases. Assemblies of gauzes, whether closely packed or spaced, can be used as the matrix in heat regenerators. Sintered packs of gauzes are a porous material with a controlled number and geometry of continuous voids, and are suitable for sweat or effusion cooling. A method for predicting the pressure drop required to pass a certain amount of gases through such assemblies would be of value and would eliminate the necessity for experimental determination.

The resistance to flow of a single gauze has in the past been treated as analogous to the drag of a cylinder. This was natural enough when the interest was primarily in controlling the degree of turbulence in wind tunnels. Each set of experimental results could be assessed on a drag coefficient—Reynolds number (based on wire diameter) basis, but could not be correlated with each other entirely satisfactorily. The analogy with flow around a cylinder has hitherto led to the use of an area porosity based on frontal area as the factor characterising the geometry of the system, sometimes referred to as the solidity ratio of the gauze. An empirical function of this porosity has been used for correlating the drag coefficients of some of the earlier experimental data.

In this paper, the resistance to the flow of air through different assemblies of wire gauzes has been correlated to a common basis. Single gauzes, closely-packed assemblies, sintered packs, and assemblies of spaced gauzes have been considered, although the actual correlations have been restricted to square-mesh gauzes with a single-wire diameter, as these are most used in practice. Experimental data for the sintered packs are presented and compared with the published data for the other types of assembly.

The flow of air through a gauze is considered as analogous to flow through passages or pipes, and the resistance as being due mainly to the friction between the flow and the surfaces of the voids in the gauze, in contrast to the previous approaches of treating the resistance of a gauze as being due to a combined drag of the wire cylinders. The range of Reynolds number (based on hydraulic mean diameter) covered by the correlation is from 0·1 to 5,000.

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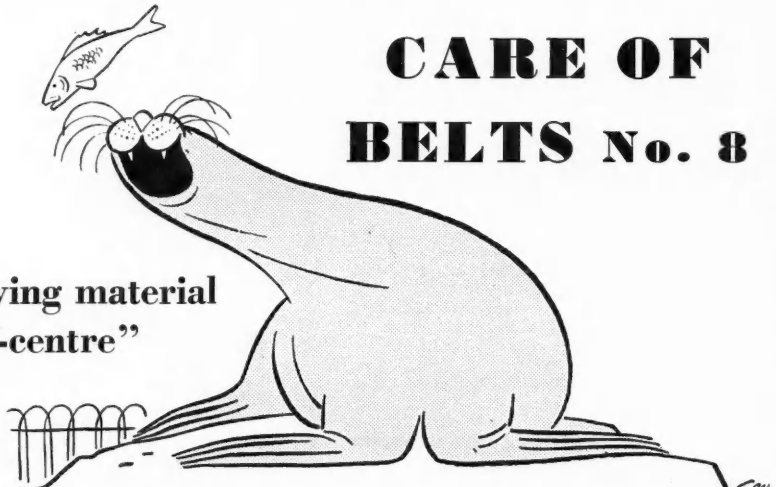

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GAS TURBINES

Convective Heat Transfer to Gas-Turbine Blade Surfaces.

By D. G. WILSON. (From an advance copy of a paper submitted to *The Institute of Mechanical Engineers, London*, July 1954, 16 pages, 21 illustrations.)

BY raising the upper temperature limit by any considerable degree, gas turbines would be invested with such significant improvements in efficiency and compactness that their adoption as prime movers in many fields would immediately be economically attractive. In a theoretical study of the effect of increasing the temperature before the first row of blades from 1250 to 2200° F in a typical two-shaft set, Brown (1950) has shown that the optimum thermal efficiency would be raised from 33·5 to 46% and that the specific mass flow would be reduced from 62 to 22 lb per hp per hr.

The task of providing efficient cooling would be greatly simplified by a knowledge of the variation of heat transfer round the surface of the blade, about which little was known at the time of writing this paper. The present research was aimed at increasing this knowledge.

In this paper, results are given of experiments into the variation, with chordwise position, of the heat transfer between the surface of a typical gas-turbine blade in cascade and in the air stream. The principal variables investigated are the blade's Reynolds number and the incident angle of the air stream, while the air/temperature ratio of the blade is kept near unity. It is shown that, with certain provisions, the results should be broadly applicable to similar blades under normal operating conditions.

The extent of the correlation of the results with values obtained by available theoretical methods is shown. The laminar boundary-layer heat-transfer theory due to Squire (1942) gives good agreement, but the predictions of heat transfer in the regions of turbulent boundary-layer flow, particularly under negative pressure gradients, leave much to be desired. In addition, knowledge of conditions at transition to turbulence and at laminar separation of the boundary layer is scanty, with consequent uncertainty in any overall heat-transfer forecast. Minor suggestions in this respect have resulted in slightly improved correlations.

The experimental method employed involved the construction of a wind tunnel having a form of contraction based on the theoretical work of Cheers (1945), which gave excellent results; also, a novel process was developed for the manufacture of the cascade blade which, it is considered, possesses certain advantages over the more traditional methods.

IRON AND STEEL

Tentative Classification of Mild Steel, Taking into Account Tendencies towards Brittle Fracture.

By G. MALMBERG. (From *Jernkontorets Annaler, Sweden*, Vol. 138, No. 6, 1954, pp. 333-349, 7 illustrations.)

USING as a basis the results obtained from studying a considerable amount of investigation material, covering mild steels intended for welding, a tentative Material Test Standard, taking into consideration the danger of brittle fracture, has been formulated.

For the investigation, the test specimen suggested by Charpy has been employed. A summary of the special characteristics of this test specimen has been given, showing that the impact-test reading of 3 kgm/cm² represents a critical value. Judged in accordance with the results of this test bar, the material can be classed as tenacious, if all test specimens of a sufficiently long series of test bars give values above 3 kgm/cm². In the tentative material test standard, this value has been more precisely suggested to be 3·5 kgm/cm².

Using this as a starting point, classification of the materials into four groups has been suggested, corresponding to different demands which can be made upon the materials.

Certain stipulations with regard to analysis and tensile strength are valid for all these steel groups. The stipulation regarding the impact resistance is regulated by the test temperature prescribed for the different steel groups. As suitable test temperatures, 0° C, — 20° C, and — 40° C have been suggested.

Finally, a study has been made of the distribution of the materials investigated over the four steel groups.

METALLURGY

A Review of Sigma Phase.

By A. J. LENA. (From *Metal Progress, U.S.A.*, Vol. 66, No. 1, July 1, 1954, pp. 86-90, 6 illustrations.)

THE first to observe the phase now designated as sigma were E. C. Bain and W. E. Griffiths in 1927; later, this constituent was identified as the compound FeCr. Because of the extremely slow rate of transformation which is characteristic of the formation of sigma in annealed alloys of high purity, the numerous investigators who followed failed to detect sigma in alloys of a proper composition, and there was considerable doubt until 1934 as to the actual existence of this new phase.

The increased demand in recent years for alloys which can be used at elevated temperatures has been the motive for many investigations of the factors responsible for the formation of sigma phase and its effect on the properties of alloys. Significant achievements of these studies include establishing of the composition limits of sigma formation in a large number of alloy systems, including many of commercial importance, such as the iron-chromium, iron-chromium-nickel and the iron-chromium-molybdenum systems; a better understanding of the influence of sigma on the properties of alloys at room and elevated temperatures; the derivation of the crystal structure of sigma; and the formulation of a number of theories to account for the formation of sigma in binary systems.

This article, which is to be presented in three parts, surveys the effects of sigma on properties for specific applications, and provides a general guide to future research in this field. This first part pertains to the compositional limits of sigma formation in alloys of the stainless-steel types, i.e., basically iron-chromium and iron-chromium-nickel alloys; the second part (to be published later) will report on the effect of sigma on the mechanical, physical, and corrosion properties of these alloys, while the third part will consider the formation of sigma in other binary and ternary alloys, the crystal structure, and the identification of sigma.

PLASTICS

Epoxy Low-Pressure Laminates.

(From *Machine Design, U.S.A.*, Vol. 26, No. 7, July 1954, pp. 125-128, 6 illustrations.)

IN a field long dominated by polyester plastics, epoxy low-pressure laminates have recently made some striking advances. Possessing several unique design advantages, these laminates have passed through their trial period and are now being used in practical commercial applications. The main delay in the development of epoxy resins as plastics for low-pressure laminating has been the concentration of development work in three other major areas, i.e., as high-strength adhesives, as potting and casting resins, and as base resins for durable coatings.

One of the chief advantages of epoxy low-pressure laminates is their high strength. Epoxy resins have exceptionally high adhesive strength, giving a good bond between the plastic and base material. Thus, epoxy glass-fibre laminates are logical materials for

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high-strength structural low-pressure laminates. In some cases, particularly with alkalis, epoxy laminates have better chemical resistance than the polyesters. Moisture resistance is excellent and absorption is low. Electrical characteristics of glass-reinforced types are at least equivalent to those of polyesters. Maximum service temperature is about the same (approximately 350° F) for intermittent exposure of high-strength types, and strength retention at high temperatures is good.

To offset these advantages, however, epoxy resins are at present more costly, although this factor could conceivably change with increased use. Furthermore, because of the very adhesion which results in higher strength, they may be more difficult to mould, although adequate moulding techniques have been developed which eliminate most of the difficulties.

With regard to practical uses, structural, chemical, and electrical applications are all excellent possibilities. An unusual example of the structural possibilities of these resins is a high-strength tank which is approximately 35% lighter than comparable steel tanks. Made by running a continuous strand of glass-fibre filament through an epoxy-resin bath and onto a low melting point alloy mould, the tank has a bursting strength of over 7000 psig. It has been tested for 10,000 cycles from zero to 3000 psig (rated operating pressure) and back to zero at 30-second intervals, without failure.

A typical chemical application is a ventilating hood, used to carry off highly alkaline plating fumes. In this application, the laminating process consists of laying up flat sheets and partial curing, using weights for pressure. Sheets are then assembled with epoxy-saturated woven glass tapes, and the assembly is given a final cure.

One major electrical use for epoxy laminates has been for printed circuits, in which the laminate serves as a base sheet of copper on one or both sides, subsequently etched to the desired pattern.

ULTRASONICS

A Distributed Transducer for Ultrasonic Power.

By J. RABINOW and M. APSTEIN. (From *Electronics, U.S.A.*, Vol. 27, No. 7, July 1954, pp. 160-162, 7 illustrations.)

TRAVELLING waves of ultrasonic energy can be set up in a long magnetostrictive rod by a distributed amplifier similar to those used in wide-band r-f service.

The distributed amplifier consists of eight stages of amplification bridged between an input delay line and a distributed plate load—excitation coils spaced along the magnetostrictive rod. The distributed ultrasonic transducer described in this article was developed as the result of an investigation into magnetic fluid clutches, entailing a search for a satisfactory method of employing magnetic clutches in the transmission of large amounts of power at cycling speeds in the ultrasonic range.

The great advantage of a distributed transducer is that it is inherently not a resonant device. Because the oscillations in the output member are excited in a space-distributed system, the mechanical length of the bar has no effect on the frequency of oscillation. This should be contrasted with an oscillating system, where the physical constants of the system determine the period of oscillation, so that the build-up of amplitude is created by successive impulses arriving in time phase with the natural oscillation of such a system. Another inherent and very great advantage of a distributed network is that the heat dissipation and therefore the energy which can be delivered to the device is much greater than that of an equivalent resonant device operated at the same frequency, because the dimensions of the former can be so much greater.

High-energy ultrasonic vibrations are now being employed in the drilling of ceramics, glass, and other hard materials. The broad-band characteristics of such transducers may have wide applications in military applications of ultrasonics. The ability to maintain a high-energy travelling wave through long lengths of material is of importance in the study of the physical properties of the materials. The stress-strain relationships obtained with steady application of forces do not hold for pulses of short duration. The rate at which pulses travel through a physical body is one of the clues to the elastic properties of the body and it has been difficult in the past to obtain pulses of high energy travelling for appreciable distances through test specimens. The ability to produce longitudinal or torsional oscillations of very large amplitude should also prove useful in the testing of materials, both in the fatigue testing of the materials themselves and in inducing vibrations in devices attached to the transducers.

THE CORRECTION OF CARBIDE-TOOL TROUBLES

(*Concluded from page* 328)

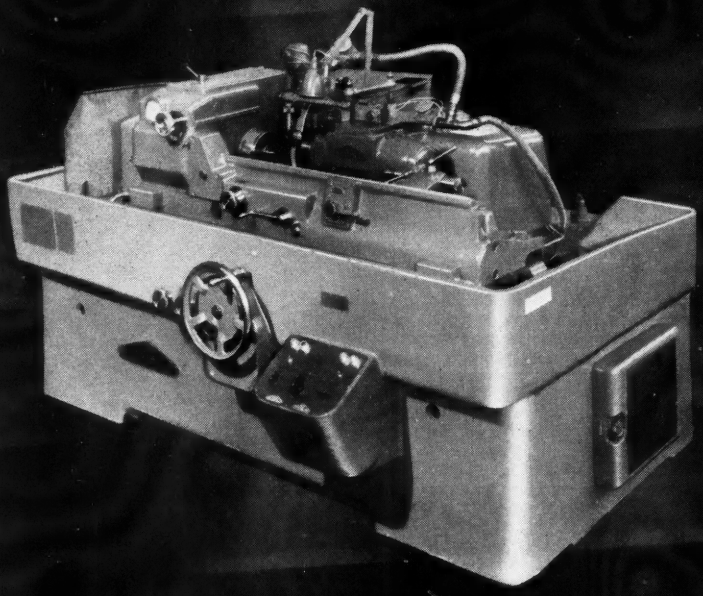
EXCESSIVE WEAR

On machines with multiple tools, any which become dull much sooner than others are considered to have excessive wear. While it may seem that the use of a harder or more wear-resistant grade of carbide will increase life, this is not often so. The material being cut, feed and speed, depth of cut, machine condition, and other factors may all contribute to excessive wear, and harder grades of carbide will fail to prolong tool life in the face of these conditions. It has been found in some instances that a softer grade of carbide or one with finer grain and more cobalt can influence tool life. Caution should be exercised when selecting carbide grades for the purpose of increasing tool life, as it is necessary to establish definitely whether minute chipping is taking place or whether wear is gradual. When cutting on non-ferrous materials, a sharp edge is of more importance than the carbide grade. If wear is on the rake surface, a harder grade of carbide may improve tool life.

Work material is one of the important factors in determining tool life. Presence of highly abrasive impurities such as silicon, or improper grain structure due to faulty heat treatment or annealing, may be the source of the difficulty.

In some instances of poor tool life, changing the coolant and flushing the machine may show marked improvement. Coolant ratios or concentration may be improper for the operation. Some experimenting with the coolant may produce beneficial results. Coolants contaminated with excessive sulphur, suspended particles, hydraulic oil, or lubrication oil will adversely affect tool life. Because of these factors, when checking coolants for the purpose of improving tool life, it is important to try a fresh tank of the existing coolant before using another type. Application of the coolant with pressure from beneath the tool may also help.

Since single-point carbide-tipped tools are the most inexpensive, the ultimate cost of excessive wear is often underestimated. Reconditioning a slightly dull tool may cost only one-tenth as much as reconditioning an excessively worn one. In some cases, regrinding costs of excessively dull tools may be nearer the price of a new tool. Excessively worn tools almost invariably cause scrap, often break, and may cause expensive machine breakdowns. Another common fault in the use of single-point tools is due to grinding-room practices. Because of apparent simplicity and low cost, such tools are usually reground by the newest or most inexperienced man. These tools should be handled and reground with the same care and caution given to more expensive tools. Rigid inspection of reground tools should be maintained, to ensure correct geometry and quality.



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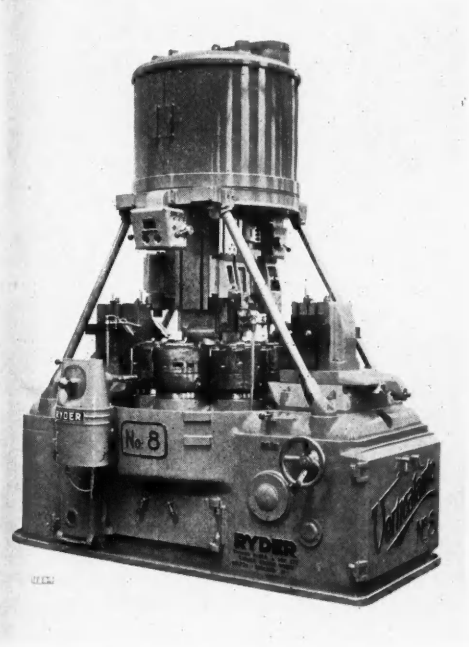
Fourth European Machine Tool Exhibition, Milan

The Fourth European Machine Tool Exhibition, some interesting exhibits of which are previewed in the following pages, will be held in Milan, between September 14 and 23, 1954. A further selection will be published in our September issue.

Their well known 6-spindle "Verticalauto" chucking automatic will be exhibited by **Thomas Ryder & Son Ltd.**, of Bolton, England. The size shown will be the No. 8, with a maximum swing of $14\frac{3}{4}$ in.

Although this machine is not new, it is relatively unique in its design. The machine has six chucking spindles, driven by 13-hp or 20-hp motors, depending on the spindle speed used. There is a total of five tooling stations, which can be used for turning, boring, chamfering, drilling, multiple drilling, and copying off a former. Each spindle, in its preloaded taper roller bearing, is mounted in an eccentric housing and bush as a complete unit, so that the spindle centre can be moved to any desired position. The speed range is normally 34 to 664 rpm.



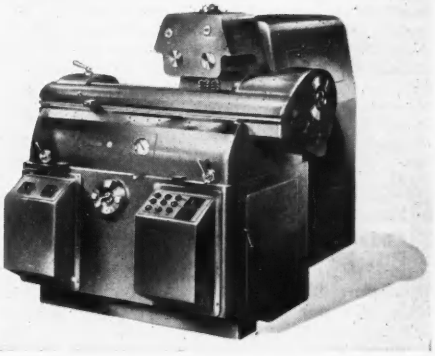
The carrier is indexed by a separate motor *via* worm gearing and a slip clutch. When indexing, the spindle carrier moves slightly past the required position, after which the motor reverses and returns the spindle against a locating catch, where it is then held firmly. The machine has five vertical slides and two horizontal facing slides, each of which covers two working stations. The vertical slides have a maximum stroke of from 10 to 12 in. All slides have rapid traverse, operated by a separate motor.

The operator locates the work in the chuck, presses the start and cycle buttons, and the carrier indexes; this is followed by the descent of the tools for operation. When the next chuck is loaded and the button again pressed, indexing will take place immediately, and the cycle has been completed. If, for some reason, the button is not pressed, the machine will come to rest after completing a cycle. The distance from centre to centre of the spindles is 15 in. and the diameter of the table neck is 14 in. The overall height of the machine is 10 ft 8 in. and its weight is 13 tons.

The machine to be exhibited will be tooled up for a motor-car flywheel, on which it will perform a large number of turning, boring, and facing operations. Carbide tools will be used throughout, the cutting speeds being of the order of 200 to 250 fpm. Output at 100% efficiency is 44 components per hour.

An advanced, high-production spline-hobbing machine, designated Type MK 6, will be shown by **Zahnräderfabrik Zuffenhausen,** of Stuttgart, Germany. It is a single-purpose machine for hobbing spline shafts and gears with straight-sided splines or teeth. The speeds and feeds, of which there are six each, are selected on an electric switch and actuated by electromagnetic clutches, while selection can be made with the machine at rest or in operation. The main spindle is mounted on four bearings and is said to be free from backlash and resistant to torsional vibration. It also has axial adjustment, so that the full width of the hob can be utilised. The depth of splines or teeth is set by adjusting the cross-slide with a handwheel graduated to 0·005 in. and 0·001 in., for coarse and fine setting respectively.

The table-ways and the table itself are inclined towards the hob for better resistance to the cutting force, and the entire cross-slide is locked solid to the machine bed by two locking handles during cutting. The table carrying the work traverses the hob, and its movement is limited by adjustable limit-switches at both ends of the stroke. The dividing head on the machine is fitted with a duplex worm gear, has axial worm adjustment for backlash elimination, and carries the work either between centres or in a chuck. All controls are grouped centrally on the front of the machine, and an automatic working cycle is available for batch or mass production. The hob first cuts with a light, preset feed, and full cutting feed is automatically engaged only when full depth is reached. After the desired cutting length is reached, the feed is automatically disengaged, and the work performs one complete



Couplings Solve Engineers' Problems

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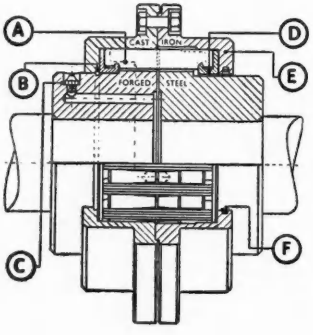
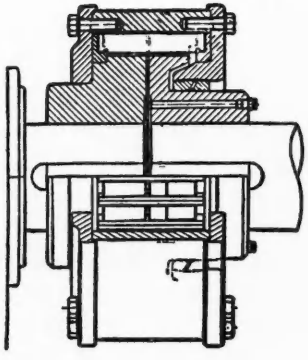
When power has to be transmitted from a prime-mover, through a shaft, to a driven machine, a number of factors have to be considered: axial mal-alignment, obliquity, torque, shock and vibration. What is the best method of overcoming all these? How can one be sure that the transit will be satisfactory? The answer to both these questions is found in Standage Flexible Couplings—couplings which have been designed to take account of the above-mentioned conditions—couplings which are proving their inestimable worth throughout industry today.

Standage Flexible Couplings are all-metal, and are supplied to suit every purpose. An outline of the standard type which fulfils the requirements of light and medium drives is shown below.



(A) Laminated Spring Silicon Steel Driving Members
(B) Spring Steel Locking Ring
(C) Oil Valves
(D) Retaining Springs
(E) Solid Flanged Cover
(F) Felt Oil Retaining Ring

It is designed to be very resilient under light torques, the resilience decreasing until it becomes sensibly constant at a pre-determined value within the range of working torques. In the event of heavy overload torques, the resilience decreases still further until, at a certain point, the coupling becomes, virtually, a solid transmitter of the drive. This condition does not come about suddenly, since the oil film between each Spring Lamination provides a cushion which could only be broken down under extreme pressure.



Another coupling is the self-supporting type. This is a modification of the standard coupling, and in order to obviate one of the adjacent bearings, a centralising device is incorporated. This comprises a spherical seating and bearing on the driven half, and serves the dual purposes of supporting the shaft and also making a perfect oil seal. Being non-rotating, wear is negligible, giving a length of service equal to that of the coupling. Another point is that this coupling eliminates the installation of a plummer block.

Space does not permit further illustrations, but information on the right coupling for your purpose will be gladly submitted. Owing to greatly expanded business, and in order to cope with increased demand, a new factory has been acquired at Newhaven, Sussex, which will soon be in full production. In the meantime, enquiries should be sent to the London works.

4th EUROPEAN MACHINE TOOL EXHIBITION MILAN

Literature describing the range of **Standage Power Couplings** can be obtained at **"The Engineers' Digest," Stand No. 5035.** where a representative will be pleased to deal with any enquiries from visitors relating to this Company's products.

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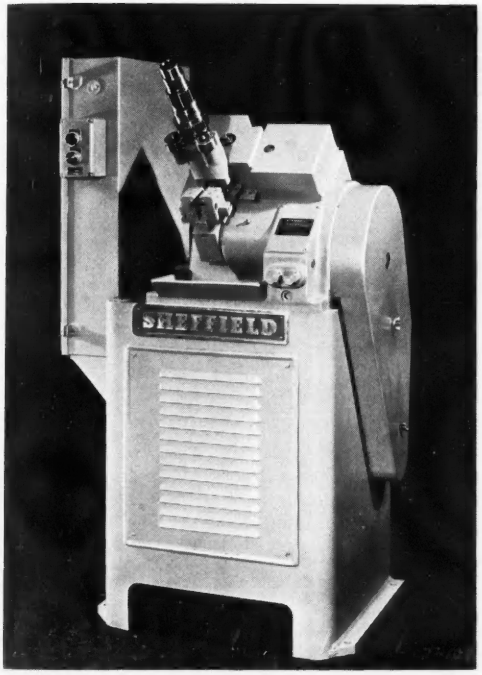
revolution, to ensure a uniform run-out on all spline ends. Rapid traverse then returns the table to the starting position. Safety interlocks are provided, so that rapid traverse and cutting feed cannot be in engagement simultaneously.

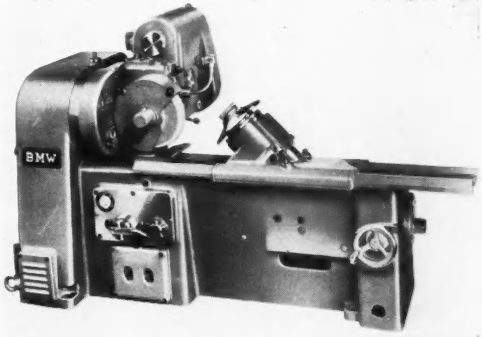
The maximum hobbing length is 25¼ in., maximum work diameter 6 in., and maximum pitch 4 D.P. Hobs up to 5⅛ in. in diameter and 5⅛ in. in length can be used, at speeds ranging from 40 to 224 rpm, and the main spindle is driven by a 6·7-hp motor. Feeds range from 0·016 in. to 0·122 in. per revolution of the work.

Deburring of gears after machining is now receiving considerable attention, as it is claimed to give gears longer life and to ensure quieter operation. Two interesting gear-deburring machines will be exhibited, one of these being manufactured by **The Sheffield Corporation,** of Dayton, Ohio, U.S.A., and the other by **B.M.W. Maschinenfabrik Spandau,** of Berlin, Germany.

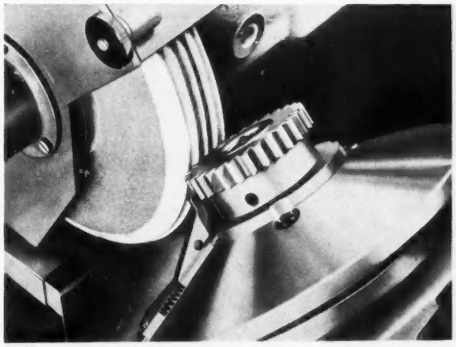


The Sheffield machine, illustrated above, uses standard cutting-tool bits and removes burrs in a "woodpecker" fashion, inasmuch as the cutter chips off the burrs in either an upward or a downward sweep. The machine has a pedestal base, enclosing a 1- or 2-hp motor, depending on the model. The motor drives the worm and worm-gear positive drive through V-belts. The worm mechanism, which actuates the cutter and indexes the gear, is completely sealed in oil, and it is claimed that no servicing, other than regrinding of cutters, is necessary. The work is driven by a drive-gear in mesh with the gear being deburred, ensuring positive location and preventing accidental incorrect indexing or slipping. Gears of a similar type, in a range of sizes, can be accommodated by using interchangeable plate-mounted tooling, comprising an idler gear and a work-locating arbor, change-over time being only 15 to 20 minutes.

The machine can handle cluster gears, planetary gears, automotive transmission gears, aircraft gears, splines, etc., and removes burrs on obtuse and acute angles, and on both flanks of spur teeth and roots, by straight chamfering or by following an involute path. It is claimed that the machine usually operates continuously without stopping for loading or unloading. Clamping is not required in most cases, but, where necessary, automatic cycle and mechanical or pneumatic clamping are available, and it is said that up to 300 teeth per hour can be deburred on the single-station model; two-station models are also available. Cutter sharpening is simple, as only the face angle requires grinding. The machine exhibited will be the model 380 A, which is suitable for external spur and helical gears up to and including 7 in. o.d. It has a 1-hp motor and is very compact, measuring only 24 in. × 23 in. × 54 in. in height, and weighing approximately 780 lb.

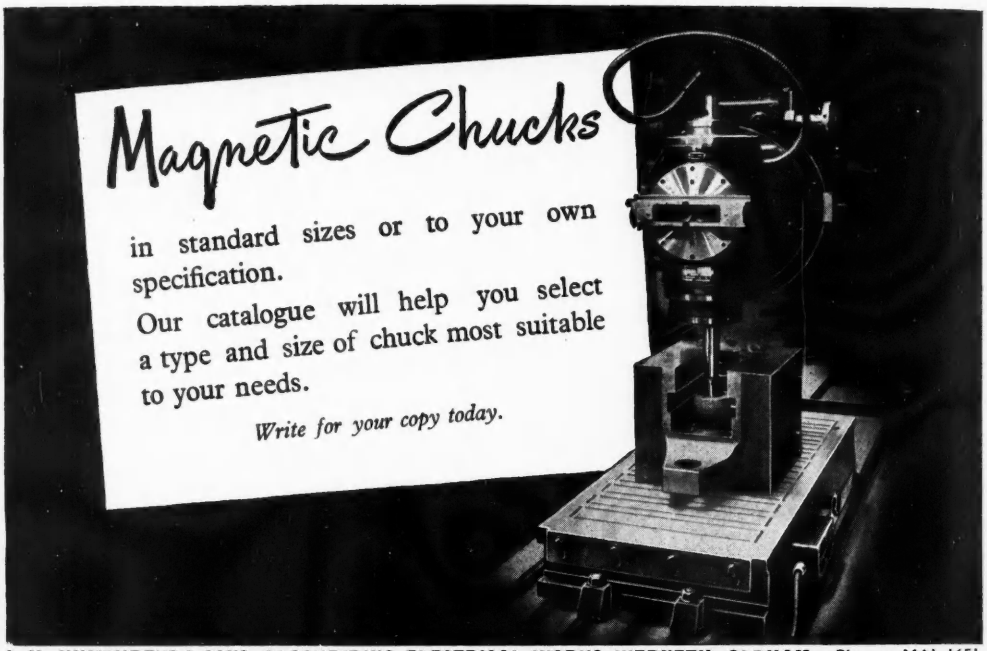


The B.W.M. machine, shown above, removes burrs by grinding, using ribbed wheels, as illustrated below.



The spindle on which the gears are mounted is set at an angle to the saddle, to produce the required chamfer angle. The saddle traverses along the bedway, movement being controlled by a lever. The movement cycle is automatically controlled to give rapid approach, feed, and rapid return. Grinding wheels can be from 5 to 10 in. in diameter, and spindle speeds from 1800 to 4500 rpm are available. The wheel and work spindles are connected by change-gears, selected according to the number of teeth on the gear to be deburred. The wheel-head can be swivelled to accommodate spur gears, as well as right- and left- hand helical gears up to 36 deg. Correct meshing of the gear teeth with the ribs on the wheel is ensured by a clutch incorporated in the drive. The wheels are rough-formed by a template-controlled diamond-dressing device, and the finished form is obtained by crushing. A hardened-steel master gear, bevelled as required and mounted on the work spindle, is used for this finish-forming operation.

The gear being deburred need not be clamped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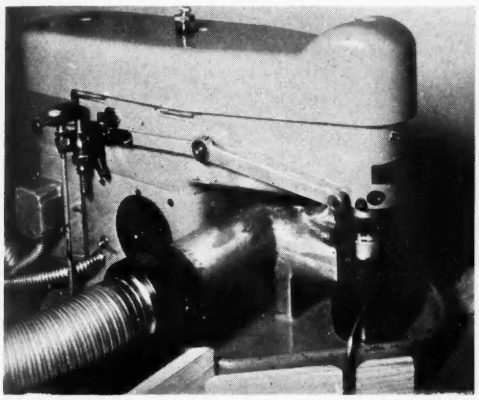
endwise and requires angular location only, by means of a key or driving peg. Loading and unloading are therefore rapid, and high production rates are possible, as the total machine cycle, i.e., approach, feed, and return, takes only a few seconds.

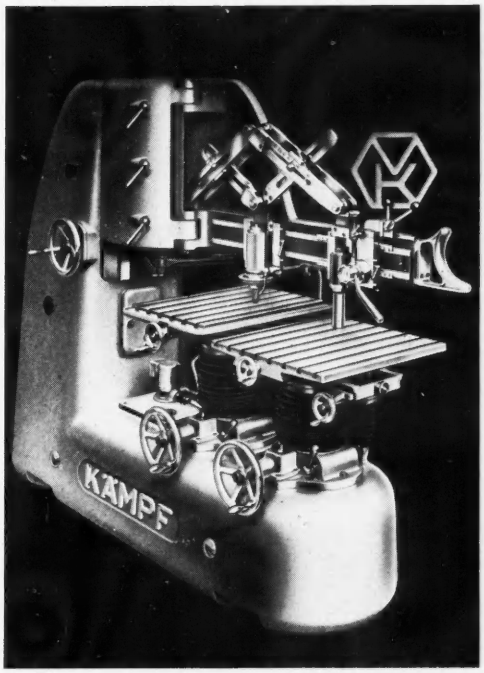
A simple, but interesting, recess-milling machine for light industries, such as those engaged in the manufacture of typewriters, office and calculating machines, sewing machines, and precision instruments, is to be exhibited by **Ebosa Ltd.,** of Grenchen, Switzerland, who specialise in high-production precision-milling machines for the above industries.

The latest addition to their range, type F-6, is semi-automatic, has a vertical spindle and can mill recesses up to 0·2 in. in width and 0·1 in. in depth. It is claimed that variations in the pre-machined component thickness have no influence on accuracy, which is up to 0·0002 in. The machine head and table are mounted on a pedestal, with a recess for the operator's legs. The pedal which operates the machine is conveniently located in this recess. The milling cutter is fully enclosed, and swarf is removed by a powerful exhaust system. Compressed air is used for cleaning the fixture and for ejecting the finished components. The main milling-spindle motor is 0·6 hp, and the exhauster motor 0·7 hp.



The operation of the machine is simple:—The depth of cut has to be set by a gauge, using the adjustment on the spindle. Depression of the foot pedal closes the cutter guard and starts the machine cycle, at the end of which the machine stops automatically. The guard opens, ejectors release the component, and compressed air cleans the fixture. A high output of 1500 pieces per hour is claimed for an experienced operator. The two main advantages of the machine are the foot-pedal operation, which replaces the conventional hand lever and frees the operator's hands, and the possibility of setting up for milling a recess to an accurate depth or, alternatively, for leaving an exact and constant amount of material in the bottom of the recess.

A light, general-purpose copy-milling machine of relatively simple design will be exhibited by **Michael Kämpf K.G.,** of Bad Homburg, Germany. The base and the vertical column form a single, integral, rigid unit and are designed for maximum resistance to deflection and vibration. A saddle, with two heavy swivel bearings, carries a swing arm with the copying pantograph, and slides in large prismatic guides, its height being adjustable to suit the operator or the work in hand. The saddle also houses the main spindle motor. The swing arm is also of robust construction, and its weight is such that it exceeds the maximum possible vertical-milling load component, thereby eliminating play in the swivel bearings under all normal operating conditions. The arm has nitrided steel slides for the tracer and milling-spindle saddles. Both these compound saddles run on adjustable roller bearings, ensuring a movement which is free from play and unaffected by wear, and facilitating the maintenance of perfect vertical alignment of the tracer and milling spindles. Copying from the master is by means of the tracer to the milling spindle *via* a pantograph system, with ratios from 1 : 1·5 to 1 : 4. A scale can be used for setting the ratio for normal work, whereas slip gauges and special setting blocks are used for precision setting.



Two separate tables are provided for the master and the work, and these are mounted on columns attached to the base. Both tables have compound movement for cross and longitudinal travel. The handwheels for these movements, as well as all other controls, are concentrated on the front of the machine for easy operation. The milling spindle, being mounted in double-row high-precision ball bearings, is capable of relatively heavy cuts at low speeds and also provides high surface finish when using small-diameter cutters at high speeds. The maximum size of work which can be accommodated with a 1 : 1 pantograph ratio is about $10\frac{1}{2} \times 8\frac{1}{2}$ in., this being reduced to about $7\frac{1}{4} \times 2\frac{1}{2}$ in. with a 1 : 4 ratio. The maximum height of the work is about 18 in., the maximum cutter diameter is 1 in., the main motor is 1·2 hp, and milling-spindle speeds range from 270 to 6400 rpm.

The main advantages of the machine are stated to include high accuracy, facility for dealing with bulky and awkward components, as the pattern and work tables are freely accessible from two opposite sides, easy operation by semi-skilled personnel, and the possibility of copying with a ratio of 1 : 1, using an additional attachment. This features reduces cutting forces and improves the finish of the work.

A new single-spindle automatic screw machine will be exhibited by **B.S.A. Tools Ltd.,** of Birmingham, England. Known as the "Metric No. 18 L," it is, as

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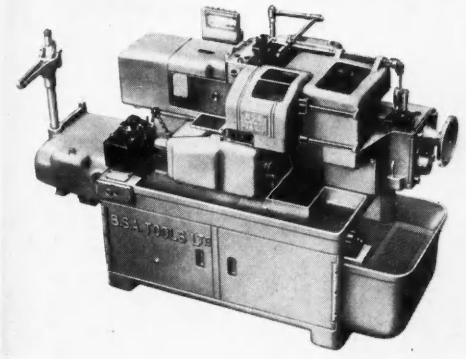
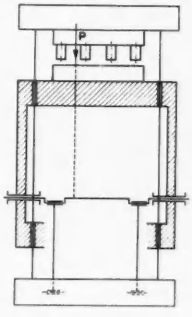
the name implies, built to metric specifications, being primarily intended for users of automatics who prefer continental-type machines. The machine has a round-bar capacity of 18 mm and is basically similar to the B.S.A. " L "-type automatics. A useful addition is a power-operated " Tecalemit " lubricating system, which automatically meters the correct amount of oil to all important bearings.

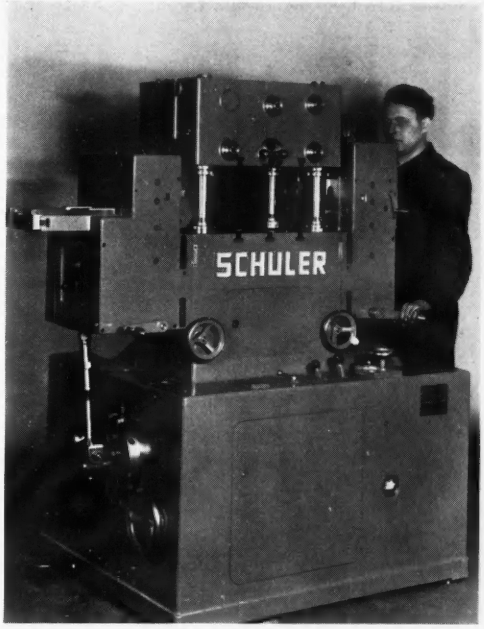


The turret incorporates a straight rapid-advance and withdrawal mechanism, which actuates the turret movement in the same position without indexing; this feature is very useful for operations such as deep hole drilling. The turret is also equipped for double indexing, the change-over from single to double indexing being quite simple. The turret bearings are lubricated by an additional hand-operated " Tecalemit " pump. The standard turret stroke of 50 mm can easily be increased to 70 mm by fitting certain conversion parts. This possibility often obviates the use of larger machines, where the length of the component is the deciding factor. The front cross-slide is operated directly from the cam by a single lever and the rear slide *via* cam-lever push-rods and the reverse-motion lever at the back of the machine. An additional single or double top-slide is rigidly mounted on the headstock and this can be used for cutting-off operations. The spindle-speed range is from 40 to 4500 rpm.

The trend in press design for the mass production of small components is reflected in machines constructed by **L. Schuler,** of Göpingen, Germany. This company will exhibit high-speed presses, generally used with multiple transfer dies and equipped with strip-feeding mechanisms. An important feature of the machines is the fact that the crank drive is built into the fully enclosed base of the machine. This has a number of advantages, including the lowering of the overall centre of gravity. When working at high speeds, this results in quieter and smoother operation. The overall height of the machine is also relatively small, so that the working parts are easily accessible and visible. The strip-feeding mechanism is driven by a stepless drive, and speeds up to 500 strokes per minute are possible.



Also of interest is the use of two connecting rods for transmitting the force from the crankshaft. This is designed to avoid misalignment of the dies, which often occurs when multiple transfer dies are used, with only one connecting rod. The centre of force



P is always between two rods, as shown schematically in the sketch. The main crank bearings are of special construction, eliminating play and thus exerting a marked influence on punch and die life, which is increased by up to 25%. This saving is due to the fact that, by eliminating or reducing bearing play, the punch does not foul the lower die, as is often the case when excessive bearing play is present.

Another interesting feature is a device for eliminating the production of incomplete parts. Experience has shown that tool life is adversely affected when strip feed does not coincide with the end of a strip and incomplete parts are punched out. When this occurs, the punch does not act on its entire surface, is deflected sideways, and fouls the die. The device used on Schuler machines automatically cuts the strip when entering and leaving the press in synchronism with the strip feed. In this way tool life is increased; furthermore, time-consuming sorting out of malformed parts is completely eliminated.

The machine is eminently suitable for the mass production of stamped parts for the electrical, automobile, watch and clock, toy, and other industries.

A somewhat unusual turning machine will be exhibited by **Kummer Frères,** of Tramelan, Switzerland. This is basically a second-operation lathe of a refined type and finds its greatest application in precision manufacture, such as watchmaking and optical and instrument production. All models of this machine have two independent headstocks mounted on a common base. The base also carries two tables on which are mounted tool-post slides and tool posts.

Operation of the machine is semi-automatic in that all tool-holder slide motions are cam-controlled and positive. Return motions are spring-operated. The operator's function is restricted to introducing the work into the chuck or collet, engaging the slide movement and spindle rotation by means of a single starting lever and, after the machine stops automatically on completion of its cycle, removing the work from the chuck. One operator can serve both heads, as they are independent; loading can take place on one head, while the

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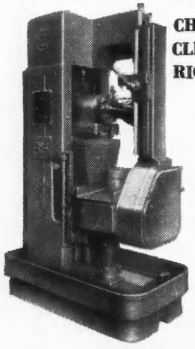
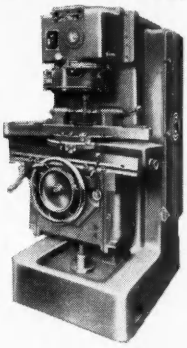
Hobbing Shaving



CHURCHILL CLEVELAND RIGID HOBBER

A typical example of accurate production



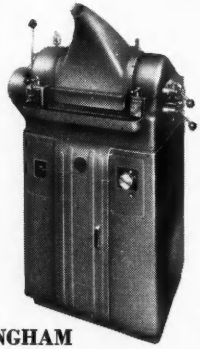
CHURCHILL RED-RING DIAGONAL GEAR SHAVER

COMPONENT : Automobile Gear—27 teeth—9·25 N.D.P. Helix Angle 26°—13′—15″. Face Width ¾″.

HOBBING : 3·5 minutes.

SHAVING : 40 sec. Removing ·002/3″ from each flank.

SOUND TESTING: 40 sec.



Sound Testing

CHURCHILL RED-RING GEAR SOUND TESTER

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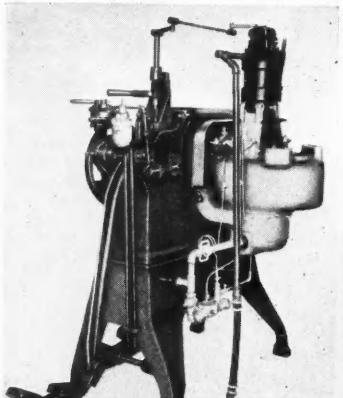
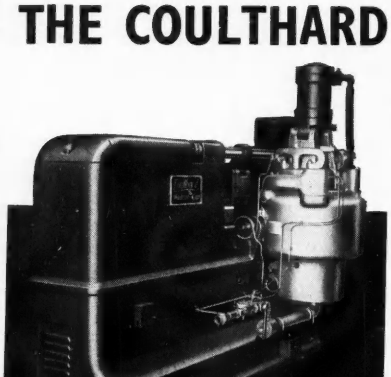


THE COULTHARD MADISON-KIPP

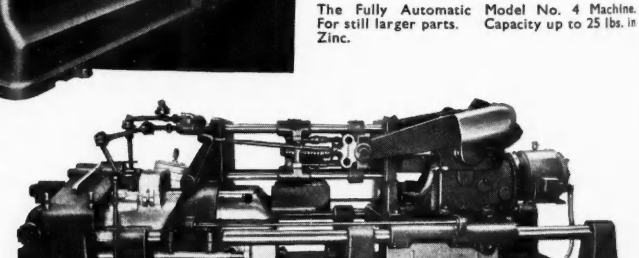
RANGE OF PRESSURE DIE CASTING MACHINES FOR ZINC LEAD TIN ALLOYS



THE GIANT KIPPCASTER MODEL 500. For Larger Zinc, Lead and Tin Alloy parts. Capacity up to 3½ lbs. in Zinc.

The Fully Automatic Model No. 4 Machine. For still larger parts. Capacity up to 25 lbs. in Zinc.

The Standard Kippcaster Model 215. The Fully Pneumatic Kippcaster is the most popular diecasting machine built today. It produces high quality Zinc, Lead or Tin Alloy parts at a higher rate of speed and lower cost. Capacity up to 1½ lbs in Zinc.



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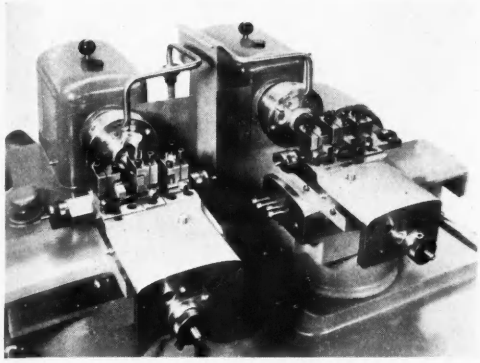
other is going through its preset automatic cycle. Adjustable stops on the sides of the tool-slide tables permit the machining of four different diameters on one component. The accuracy of these diameters is independent of cam accuracy and can be adjusted individually by micrometric fine setting of the stops. The base houses the motors and their controls, as well as the coolant pump. A variety of external and internal collet and chucking fixtures is available.



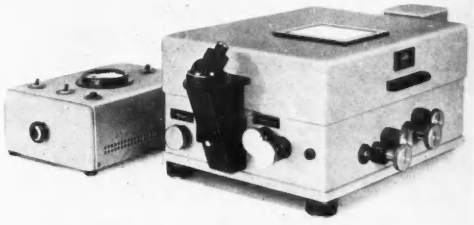
These machines are made in a range of models, each particularly suitable for a given type of work. The headstock-spindle speed ranges are either 325 to 2700 rpm, or 410 to 3360 rpm. Stepless variable-speed drives are available on request. The machine actually exhibited will be the model MR, which has relatively large capacity and can be set up for copy machining. It is used for production of parts for sewing machines, office machines, bearings, bicycles, etc. The advantages claimed for all these machines include extreme precision and production of fine finishes, machining of complicated forms without the use of form tools, and high production rates.

A wide variety of industrial electrical and electronic apparatus, including industrial television equipment, will be exhibited by **Philips,** of Eindhoven, Holland. The television equipment consists of a camera, a monitor, and slave units, offering such advantages as high resolution, built-in two-way telephone system between monitor and camera, and compactness.

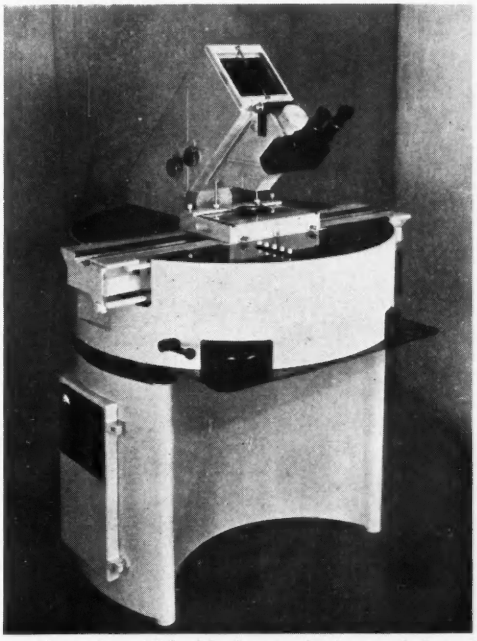
The applications of industrial television are many and varied, and include use in railway shunting yards for reading labels and numbers on wagons from a central point, in gas works as a safety device for coke ovens when the load is discharged, and the reading of measuring instruments at a safe distance in experiments or processes entailing the risk of explosion. Finally, destructive tests on metals, when there is a risk of flying metal, can be watched closely and in safety on a television screen.

Strain gauges and their accessories will form another part of the general exhibit. The design and applications of strain gauges for strain and deformation measurement are well known. Philips, however, offer a number of special pick-ups used in conjunction with standard measuring bridges for the conversion of mechanical values into measurable electrical quantities. These include a water-pressure pick-up, dynamometers of various types, displacement pick-ups, and an accelerometer.

A comprehensive range of measuring and optical instruments is to be exhibited by **Carl Zeiss,** of Oberkochen, Germany, including a gauge-block comparator, which is a development of the earlier Zeiss interference comparator. It is intended for absolute and comparative measurement of gauge blocks up to a length of 4 in. The new instrument,



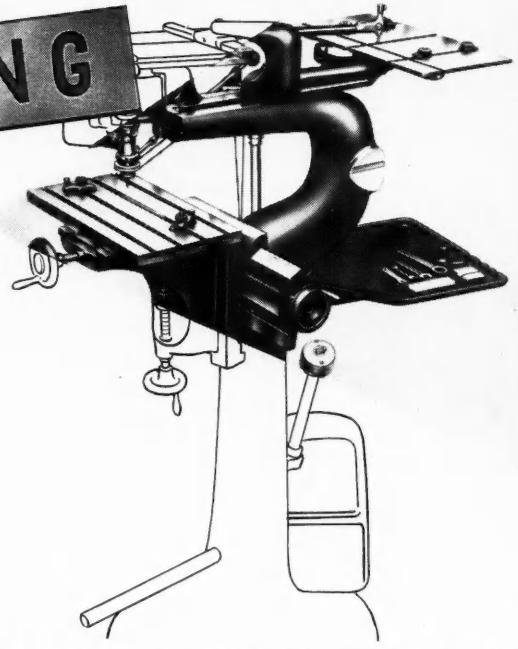
illustrated above, achieves the same accuracy as its predecessor, but is simpler and can be used by semi-skilled personnel. The estimation of the displacement of interference bands, normally subject to the human element, is replaced in the new instrument by an objective measuring system.



Also to be exhibited is the completely new design of universal measuring microscope illustrated above. It differs considerably from the older types in that it employs binocular observation, a new departure in the field of industrial optical measurement. The instrument has a simple and functional appearance and all accessories, including the plane stage, centre cradles, V-jaws for location, illuminating, projection, and photographic equipment, circular stage with graduated scale, and all electrical equipment are neatly incorporated in the general construction. The measuring scales, which are 4 in. and 8 in. in length, permit readings to 0·00004 in. The circles, graduated to angles of 1 minute, can be selected by push-buttons while observation through the inclined binocular tube is in progress.

The Zeiss interference microscope is another interesting instrument, and is designed for testing the finest machined surfaces. The surface examined is

ENGRAVING



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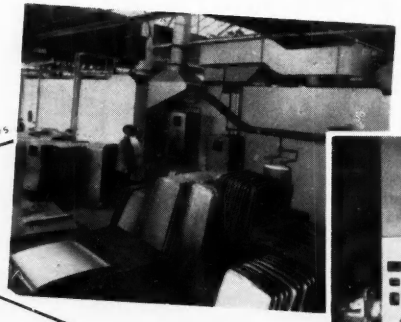

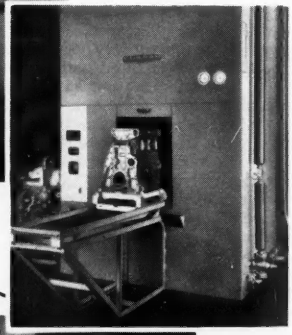

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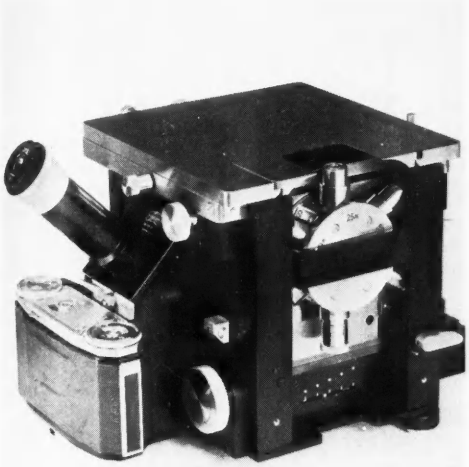


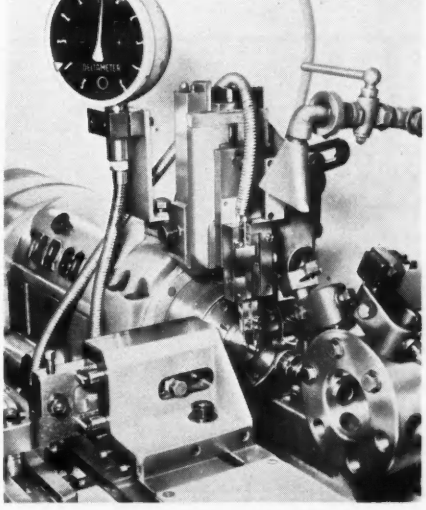
microscopically enlarged and its surface structure is shown by a contour-line representation. The range of measurement is from 2μ to 0·03μ, and monochromatic or white light can be used. This instrument, shown above, is also intended for use by semi-skilled operators.

Optical instruments for viewing internal surfaces will be exhibited by **J. Bodson & Fils,** of Puteaux (Seine), France. These endoscopes consist of an objective, a number of transmission lenses, an eyepiece, and a light-source for illuminating the internal surface to be viewed. All these components are mounted in rigid tubes of appropriate diameters and lengths, depending on the required application. Bores down to about $\frac{1}{4}$ in. in diameter can be viewed to a depth of about 100 times the diameter; large bores of 11 to 15 in. in diameter can be inspected to a depth of about 22 ft. Magnification varies according to the distance of the objective to the surface being examined, and ranges from full size to $\times 3$ or $\times 4$. A range of hinged or in-line objective units permits the observation of internal surfaces in a variety of positions.

A miniature photographic camera can be used in conjunction with the apparatus, so that a permanent record of internal surfaces can be made. This, however, applies only to instruments with a minimum diameter of $\frac{1}{4}$ in. These instruments have many varied applications, including the inspection of long bores, engines of various types, tubes, and gas cylinders, as shown in the illustration.

A wide range of measuring instruments and gauges, including a number of variations of "Deltameter" gauges for continuous measuring during machining operations, will be exhibited by **C. E. Johansson**, of Eskilstuna, Sweden. The "Deltameter," Model A, is particularly interesting in that it is used on automatic lathes. The instrument is operated by compressed air and contains a balanced measuring system, which is unaffected by normal line-pressure fluctuations. The movement of the tungsten-carbide tipped knife-edge measuring head is transmitted to the dial pointer through a special valve. Pointer movement is always smooth and unaffected by vibration, since the transmitting medium is air. The measuring head is suspended by springs in the holder, which is mounted on a convenient point on the machine. The measuring tips are parallel knife edges, the parallelism of which is adjustable. The dial indicator has a large, clear scale and two individually adjustable tolerance pointers. Two electric contacts are built into the indicator and these can be set individually from the exterior. They are used as limit contacts and can actuate light or sound alarm signals, can instantaneously switch off the machine, or can operate an automatic "statistical control" system.

The standard instrument measures up to 0·4 in. in diameter, and the two alternative measuring ranges are $\pm$ 0·002 in. and $\pm$ 0·004 in. The scale divisions are 0·0005 in. and 0·001 in. respectively, and the distance



between divisions is approximately 1·2 in. It is claimed that the measuring accuracy is $\pm$ 0·00005 in. or $\pm$ 0·0001 in., depending on the range used. The sensitivity of the electric contact is 0·00002 in., when using the finer range. Air pressures from 28 to 42 psi are suitable for operating the instrument, consumption being about 10 cu ft per minute. The electric contacts operate from an a.c. or d.c. supply of 6 to 12 V. Among the advantages the instrument is stated to offer are a small risk of rejects, greater safety in production, the possibility of one operator serving several machines, and, in most cases, the elimination of the need for inspecting finished parts.

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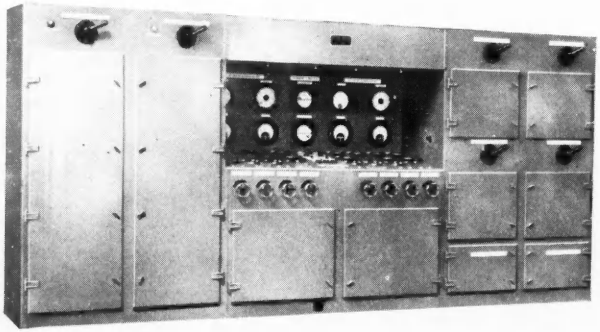

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NEWS OF THE MONTH

PERSONAL

Mr. Colin John Barker has been appointed general managing director of the Wellman Smith Owen Engineering Corporation Ltd. **Mr. Frederick Harold Brooks** has been appointed managing director in charge of production and technical development.

Mr. F. W. G. Beaumont, Mr. L. B. H. Hallett and **Mr. N. A. W. Stacey** have been elected directors of Austinlite Ltd. and Sumo Pumps Ltd., subsidiary companies of Stone-Chance Ltd., 28 St. James's Square, London, S.W.1. **Mr. T. O. Orr** has been elected a director of Sumo Pumps Ltd. **Mr. John Raymond** is managing director of Stone-Chance Ltd. and a director of both subsidiary companies. The other directors of Stone-Chance Ltd. are **Mr. Bryan Preston** (chairman), **Mr. A. J. S. Brown** and **Mr. P. A. Peterson.**

Mr. F. Baker Bennett, A.M.I.Mech.E., A.M.I.P.E., has been appointed technical representative of the recently formed Non-ferrous Machine Tool Division of Wadkin Ltd., Leicester.

Mr. H. G. Boullen, B.Sc.(Tech.), A.M.I.E.E., has been appointed home sales manager of Lancashire Dynamo & Crypto Ltd., St. Stephen's House, Victoria Embankment, London, S.W.1.

Mr. R. G. Braithwaite, M.I.C.E., director and welding consultant to Braithwaite & Co. (Structural) Ltd., has been installed as President of the Institute of Welding, in succession to **Mr. A. Robert Jenkins, J.P., M.I.Mech.E. Mr. R. E. G. Weddell,** joint managing director of W. G. Allen & Sons (Tipton) Ltd., has succeeded Mr. Braithwaite as vice-president of the Institute.

Mr. F. H. S. Brown, M.I.Mech.E., M.I.E.E., has been appointed generation design engineer at headquarters of the British Electricity Authority, in succession to **Mr. F. Shakeshaft,** who will be concentrating on future design and special generation problems. **Mr. W. B. Shannon, M.I.C.E., M.I.Mech.E., M.I.E.E.,** has been appointed chief generation engineer (construction) of the London division of the Authority.

Mr. William Casson, M.I.E.E., system design and development engineer of the British Electricity Authority, has been appointed transmission design engineer, in succession to **Mr. F. J. Lane, O.B.E., M.Sc., M.I.E.E.,** who has been recently appointed deputy engineer (transmission) of the Authority.

Mr. F. G. Cook has been appointed commercial manager of Marconi Instruments Ltd., St. Albans.

Mr. J. S. Elliott, Principal of Gateshead Technical College, has been appointed Principal of Rutherford Technical College, Newcastle-upon-Tyne, in succession to **Dr. H. A. Scarborough,** who is to retire.

Viscount Falmouth, M.I.Mech.E., has been re-elected President, and **Sir Harold Roxbee Cox, Ph.D., D.I.C., B.Sc., M.I.Mech.E., F.R.Ae.S., Dr. S. F. Dorry, C.B.E., M.I.C.E., M.I.Mech.E., F.R.S.,** chief engineer surveyor of Lloyd's Register of Shipping, **Major-General H. R. B. Foote, V.C., C.B., D.S.O.,** director-general, Fighting Vehicles Division, Ministry of Supply, and **Vice-Admiral (E) F. T. Mason, C.B.,** Engineer-in-Chief of the Fleet, have been re-elected vice-presidents of the British Internal Combustion Engine Research Association. **Mr. G. W. Bone, Mr. J. Calderwood, Dr. A. R. Morcom** and **Mr. A. V. Wilkin** have been elected to the Council, which also includes **Mr. H. D. Carter, Mr. C. G. Tangye** and **Mr. G. A. McMillan.**

Mr. Ralph Gabriel, M.A.(Cantab.), production director of the Scotswood Division, **Mr. Roy H. McCall, B.Sc., A.M.I.Mech.E.,** sales director, and **Mr. G. K. E. McCall, M.A.(Cantab.), A.M.I.Mech.E., A.M.I.P.E.,** production director of the Halifax Division, have been appointed to the Board of Churchill-Redman Ltd., Halifax.

Mr. L. A. M. Ginger, A.M.I.E.E., has been appointed assistant chief electrical engineer of the London Transport Executive, 55 Broadway, London, S.W.1. **Mr. N. Branton** has been appointed assistant electrical engineer (generation) with responsibility for all three power stations at Lots Road, Neasden and Greenwich, of the Executive.

Mr. John Hilton, O.B.E., M.I.Mech.E., and **Mr. C. D. H. Webb, A.I.E.E., A.I.Mech.E.,** have been appointed executive directors of The Plessey Co. Ltd., Ilford, Essex. Mr. Hilton is general manager of the Aircraft Mechanical Division and Mr. Webb is general manager of the Aircraft Electrical Division of the company.

Mr. F. A. Hurst, chairman, and **Mr. C. F. Hurst** and **Mr. F. A. Martin,** directors of Samuel Osborn & Co. Ltd., Clyde Steel Works, Sheffield, have been elected to the Board of Low Moor Alloy Steel Works Ltd., Bradford, **Mr. C. F. Hurst** and **Mr. F. A. Martin** have been appointed joint managing directors of this recently acquired subsidiary company of Samuel Osborn & Co. Ltd.

Air Vice-Marshall A. L. James, C.B.E., B.Sc., D.I.C F.R.Ae.S., has been elected to the Board of the Bristol Aeroplane Co. of Canada Ltd. and of its subsidiary company, Bristol Aero Engines Ltd. He will assume his position as vice-president of engineering of Bristol Aero Engines Ltd. on September 1st.

Mr. L. C. Jarman, A.M.I.E.E., has been appointed group personnel officer of Metal Industries Ltd., Victoria Station House, London, S.W.1.

Mr. B. C. Lovatt has been appointed chief engineer of the Parsons Engineering Co. Ltd., Southampton.

Mr. James C. Macfarlane, O.B.E., Wh.Sc., M.I.E.E., has relinquished the office of managing director of Macfarlane Engineering Co. Ltd., Netherlee Road, Cathcart, Glasgow S.4, but remains chairman of the company. **Dr. J. W. Macfarlane, Wh.Sc., M.I.E.E., J.P.,** has been appointed managing director and **Mr. C. C. Macfarlane, M.I.E.S., M.I.W.,** an additional director. **Mr. A. W. Muir** has been appointed secretary of the company and **Mr. W. I. Macfarlane, Wh.Sc., B.Sc., A.R.T.C., A.M.I.E.E.,** remains a director and is responsible for electrical designs.

Mr. Kenneth V. Mason has been appointed assistant general manager, **Mr. Douglas H. Outwin,** sales manager, and **Mr. G. F. H. Lefroy,** works manager, of the Materials Handling Division of The Yale and Towne Manufacturing Co. Ltd., Wednesfield.

Mr. J. S. Morton, D.F.C., has been elected a director of Electro-Chemical Engineering Co. Ltd., Netherby, 161 Queens Road, Weybridge, Surrey.

Mr. E. J. Nicholl, B.Sc.(Eng.), A.F.R.Ae.S., has been elected joint managing director of Dowty Equipment Ltd., Cheltenham, in conjunction with **Mr. G. H. Dowty. Mr. Nicholl** has also been elected managing director of Dowty Fuel Systems Ltd. **Mr. G. H. Dowty** will continue as chairman of both companies. **Mr. F. J. A. Mangeot** has been elected a director of Dowty Fuel Systems Ltd. **Mr. R. C. Cussons, D.F.C., M.A.(Cantab.), F.R.Ae.S.,** has been appointed chief designer of Dowty Equipment Ltd.

Mr. W. E. Nixon, F.C.I.S., deputy chairman and managing director of the de Havilland Aircraft Co. Ltd., Hatfield, Hertfordshire, has been elected chairman of the company, in succession to **Mr. F. T. Hearle, C.B.E., F.R.Ae.S., M.I.P.E.,** who has relinquished the chairmanship on medical advice. **Mr. F. E. N. St. Barbe,** deputy managing director, has been elected vice-chairman.

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Mr. W. D. Pacey has been appointed commodore engineer of the Peninsular and Oriental Steam Navigation Co., 122 Leadenhall Street, London, E.C.3.

Mr. A. W. Page, M.B.E., T.D., M.I.P.E., has been appointed London manager of the Igranic Electric Co. Ltd., in succession to **Mr. N. V. Baldwin, T.D., M.I.E.E.,** who has been appointed managing director of Brookhirst-Igranic S.A. (Pty.) Ltd., the subsidiary company of the electrical division of Metal Industries Ltd., Victoria Station House, 191 Victoria Street, London, S.W.1.

Mr. Mark Radivan has been appointed chairman and managing director of De Bergue Machine Tools Ltd., Strangeways Ironworks, Manchester 3. **Mr. R. H. Moon** has been appointed a director of the company.

Mr. S. Roberts has been appointed deputy managing director and general sales manager of Hoover Ltd., 211/213 Regent Street, London, W.1, following the retirement of **Mr. F. H. Bunn** after 33 years of service to the company.

Mr. James Sinstadt, A.M.I.Mech.E., manager of A. Schrader's Son Ltd., Birmingham, has been elected a director of the American parent company, A. Schrader's Son, Inc.

Mr. C. P. Storr, M.A.(Cantab.), M.I.Mech.E., M.I.E.E., has been appointed manager of the Dominions Division of the Metropolitan-Vickers Electrical Export Co. Ltd., Trafford Park, Manchester 17.

Mr. J. D. Thorn, M.A., A.M.I.Mech.E., has been appointed chief engineer of the engine department of Ruston & Hornsby Ltd., Lincoln, in succession to **Mr. I. Wans, A.M.I.C.E., M.I.Mech.E., M.I.Mar.E.,** who has resigned from the company.

Mr. L. C. W. Turner has been appointed sales director of Brush Electrical Engineering Co. Ltd., Loughborough, a subsidiary company of the Brush Group Ltd. Mr. Turner has been with Crompton Parkinson Ltd. for the past 22 years; he was manager of their Belfast office and later North-West area manager operating from Manchester.

Mr. R. M. Tyrrell has been appointed manager of the London office at 131 Victoria Street, S.W.1, of B. and S. Massey, Ltd., Openshaw, Manchester.

Mr. Jack Walford has been appointed to take charge of the tecnnical department for pneumatic equipment of Benton & Stone Ltd., Aston Brook Street, Birmingham 6, in succession to **Mr. C. Willcox,** who resigned to rejoin his family business, P. L. Willcox Ltd., brassfounders and engineers, Tyseley, Birmingham. **Mr. Arthur Smith** is manager of the technical sales department for industrial lubricating systems of the company.

Mr. R. W. Walker, chief designer of the Gloster Aircraft Co. Ltd., Hucclecote, Gloucestershire, has been elected technical director of the company, in succession to **Mr. W. G. Carter,** who has retired.

Mr. R. Willis, works director, and **Mr. P. E. H. Wilde,** sales director, of Darwins Ltd., Sheffield, have been elected to the Board of Sheffield Forge and Rolling Mills Co. Ltd., which has recently been acquired by the Darwins Group.

Mr. J. Wright, O.B.E., F.R.Ae.S., director and general manager of the Dunlop Rim & Wheel Co. Ltd., Coventry, has been elected a director of the Dunlop Rubber Co. Ltd.

B.S.I. EXPORT PANEL

The British Standards Institution announces the formation of a small Export Panel consisting of leading industrialists who are actively engaged in the markets of the world. The Panel will advise B.S.I. on how best it can assist export trade.

The development of national standards in overseas countries has a direct bearing on British manufacturers' export activities, and therefore demands that British industry should, through the B.S.I., take a leading part in influencing developments in the international standards field. Fundamentally B.S.I.'s job in this sphere is to limit the necessity for British manufacturers to produce a variety of goods to comply with a variety of different standards in different countries. To enable manufacturers to take account of other countries' standards in their production for export, B.S.I. provides British industry with a complete service of information about overseas standards; and it is equally necessary that in formulating British Standards full account should be taken of the requirements of export markets as expressed in their own standards.

The proper execution of this service to British industry calls for the best guidance which exporting industry can offer to B.S.I., and it is on these levels that the new Export Panel will operate. One practical task will be to suggest ways in which the use of British Standards overseas can be promoted, and how availability of British Standards in all parts of the world can be improved.

Formation of the new Export Panel has been actively helped by the Federation of British Industries, which at a recent export conference urged the need for further attention to these questions. The initial constitution of the new Panel is as follows:—

Mr. J. L. S. Steel (Imperial Chemical Industries, Ltd.) Chairman; Mr. G. H. Andrew (Under Secretary, Board of Trade); Mr. D. Maxwell Buist (British Electrical & Allied Manufacturers' Association); Mr. Leslie Gamage, M.C. (General Electric Co., Ltd.; President, Institute of Export); Sir Ernest Goodale, C.B.E., M.C. (Warner & Sons, Ltd.; President of the Silk & Rayon Users' Association); Mr. Hector McNeill (Babcock & Wilcox, Ltd.); Mr. J. W. Ridgeway (Edison Swan Ltd.) and Mr. R. L. Wills, M.C. (National General Export Merchants' Group & London Chamber of Commerce).

THE S.B.A.C. DISPLAY, 1954

This year there will be a record number of exhibitors at the S.B.A.C. Display, which is due to take place at Farnborough, Hampshire, 6th-12th September. 281 Members of the Society (compared with 244 in 1953) will be exhibiting their products for all the world to see.

It is not yet possible to give a full list of all the aircraft which are likely to be on view. The flying programme will start this year with a demonstration of the *Pembroke* and *Heron* feeder-liners, both of which are being delivered to purchasers abroad. Simultaneously two flying test-beds, the *Ambassador* with Proteus engines and the *Varsity* powered by the *Eland*, will take the air.

There will be a display of light single-engined machines suitable for communications, executive and training duties, as well as private flying. The *Beaver*, *Provost*, *Aiglet* Trainer and *Pioneer* will fly in this group.

Military aircraft will follow the civil planes, to demonstrate the high speed and performance achieved by the Service aircraft of today. Three *Canberra* bombers, each with different engines, a *Sea Hawk*, a *Hunter*, a *Meteor*, a *Gannet* and a *Balliol* will all be shown in the short space of fifteen minutes.

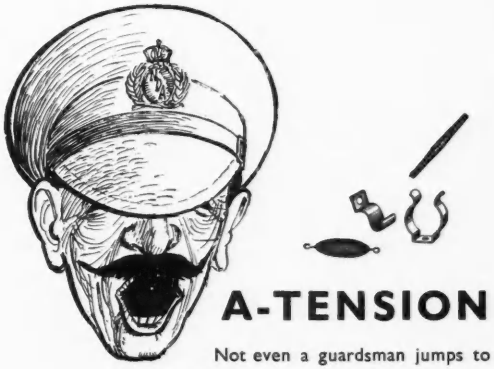
The turn of the helicopters comes next. A group composed of the *Sycamore*, Bristol 173, Jet Gyrodyne, and two *Skeeters* will be demonstrated.

Finally there will be individual demonstrations of Britain's latest civil and military aircraft. The public will see the three V-bombers, *Valiant*, *Victor* and *Vulcan*. The *Valiant* is already beginning to be delivered to the R.A.F. to complement the equipment of its heavy bomber squadrons.

The newest marks of *Comet* will be demonstrated, and this will be the first public appearance of the *Comet* 3. The striking differences between *Comet* 3 and 2 will be readily apparent in the air.

The R.A.F.'s first jet trainer will be displayed. Called the *Jet Provost*, this aircraft bids fair to revolutionize training methods by reducing the time spent by pilots under instruction.

Anti-submarine and experimental aircraft will be put through their paces, and the Display will end with fighters exhibiting their ability to defend Britain against attack, even at speeds exceeding the speed of sound. Here, performances will be given by the *Hunter*, *Swift*, 525, and *D.H.* 110. The Display will end with a demonstration by five *Javelins*, showing the manœuvrability of the R.A.F.'s new all-weather fighter.



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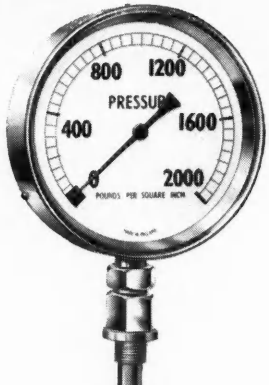

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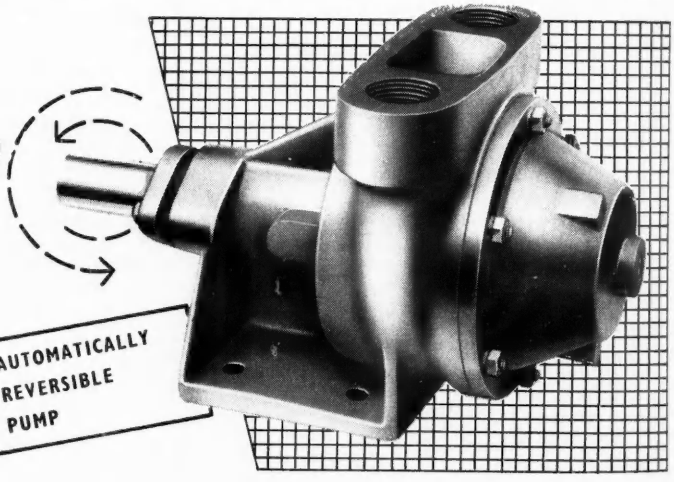

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STANDARD TELEPHONES AND CABLE'S NEW FACTORY IN SOUTHAMPTON

The industrial potential of Southampton is shortly to be increased by the erection of a new factory at Southampton New Docks by Standard Telephones and Cables Limited which will be equipped with the latest machinery and facilities for the production of submarine telephone cable and submerged repeaters.

A nucleus of experts and technicians in the fields of engineering and manufacture from the Standard Telephones and Cables' organization at North Woolwich, London, will initially start this new factory but it is anticipated that the main body of the personnel will be obtained from local districts.

The selection of Southampton for this new and important branch of the electrical engineering industry was made because of the town's position with regard to rail and sea access, both of which are important in the manufacture and shipment of this type of cable and equipment to world markets.

In order to lay cables and repeaters on the sea bed, cable ships are employed and the cable is fed straight from the factory into the specially designed holds of the cable ship. The British Post Office Cable Ship "Monarch," the largest cable ship afloat, having a gross tonnage of 8056, can carry between 5000 and 6000 tons of cable. The proposed site of the factory at Southampton New Docks is therefore ideally suited to this purpose, with good docking facilities and ready access to deep sea water and the world's sea routes.

Submarine cables and repeaters are complementary to radio links for the passage of speech across wide river estuaries, seas, and oceans, but whereas conversations by radio may be subjected to fading and interference, they may be passed over a short submarine cable without any effective loss of quality. However, if the cable is very long the received speech might be weak and unintelligible due to electrical losses, and it is, therefore, necessary to insert repeaters at regular intervals. These devices are valve amplifiers which boost the signals so that a satisfactory volume of speech is given at the far end of the cable.

The cable and repeater units have obviously to be very strong, corrosion-proof, and completely watertight, to withstand laying on the sea bed in deep water where pressures from five tons per square inch may be encountered. The valves and other electrical components in the repeater units must operate without fault or failure for periods of many years and arrangements have to be made to pass electrical power along the length of the cable to feed the valve circuits.

This new factory will be capable of producing submarine telephone cable and repeaters to span the seas and oceans of the world.

PETTERS LIMITED

An opportunity was afforded the Technical Press last month of visiting Petters Limited, of Staines, to visit their workshops and to see the production of their model PAZ-1 engine, which is stated to be the smallest all-purpose diesel engine on the market, and which was recently awarded the Silver Medal at the Bath and West Agricultural Show. This engine is a cold-starting, air-cooled, single-cylinder, four-stroke engine, developing 1½ to 2½ bhp at 1000 to 1500 rpm, and is, in fact, the diesel version of a long established Petter petrol engine, all major components of both versions being interchangeable.

During the visit to the workshops, it was, of course, impossible to show the production of the PAZ-1 engine separately from that of the other engines in the Petter range, as the works are deliberately laid out to make the maximum use of machine tools, conveyors, etc. This also signifies better service facilities, as some of the component parts are common to several engines.

TILTMAN LANGLEY LABORATORIES LTD.

A new London office, to undertake full-scale layout for aircraft and other industries, has been opened by Tiltman Langley Laboratories Ltd., of Redhill, Surrey, who are using a lithographic process of preparing detail plates for lofting.

In this process, the initial layout is drawn in cellulose ink on an aluminium plate with a grained surface. Depending on the application, various items of information, not usually given on a drawing in this form, are shown. This plate is then "inked up," i.e., the lines on the plate are given a coating of printers' ink, or inert transfer ink. A transfer plate is then placed in contact with the layout, and both are pressed together. On separation, an image is retained by the transfer plate, which will have absorbed an impression of the layout in the ink. The transfer plate is then placed in contact with the material upon which a reproduction is desired, and both are subjected to pressure. This will again transfer an impression onto the selected material. The process may be repeated several times before the plate requires re-charging.

If it is desired to print onto another grained plate, inert ink is substituted for printers' ink. This will give a visible impression, but will not ink up with the new layout. Thus, selected lines may be drawn with cellulose ink, and unnecessary lines omitted.

CURRENT AMERICAN PRACTICE IN HEATING, VENTILATING AND AIR CONDITIONING

The Institution of Heating and Ventilating Engineers have arranged to hold a special meeting on Tuesday, 14th September 1954, when Mr. John K. M. Pryke, B.Sc.(Eng.), M.I.H.V.E., A.M.I.C.E., M.Amer.S.M.E., M.A.S.H.V.E., Consulting Engineer, of New York, U.S.A. will present his paper on the above subject. The meeting will be held in the Lecture Hall of the Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, and will commence at 6.0 p.m.

THE ROCHDALE PROCESS

In the Classified Abstracts section of our issue for April, 1954, we reviewed a paper, presented on March 12, 1954 by Messrs. Nicklin and Redman, of the North Western Gas Board's Production Department, to the Manchester Section of the Institution of Gas Engineers. This paper, entitled "The Rochdale Process," described a method developed over the past three years, whereby the throughput on orthodox vertical retorts can be more than doubled, with very small outlay on plant modification.

This new process is now in commercial operation at the Partington works, near Manchester, where sixteen retorts, with a nominal capacity of two million cubic feet, have been converted. An additional sixteen retorts are to be converted later.

FOURTH EUROPEAN MACHINE TOOL EXHIBITION

The 4th European Machine Tool Exhibition which will take place in Milan from 14th to 23rd September, 1954, is assuming larger proportions than all previous machine tool shows.

Whilst the Paris, Hanover and Brussels Exhibitions have occupied less than 350,000 sq. ft., in Milan 842 firms from 13 countries have already booked 410,000 sq. ft. of exhibition space for the display of more than 11,000 tons of machine tools and allied equipment.

DUTY-FREE IMPORT OF MACHINERY

The Report of a Committee which was appointed by the President of the Board of Trade in March, 1953, to consider the duty-free admission of machinery into the United Kingdom, has now been published by H.M. Stationery Office. Recommendations of the Committee include :—

1. Some discretionary system to permit the duty-free entry of machinery is in the national interest, but we do not recommend the continuation of a general scheme such as that which has obtained hitherto.

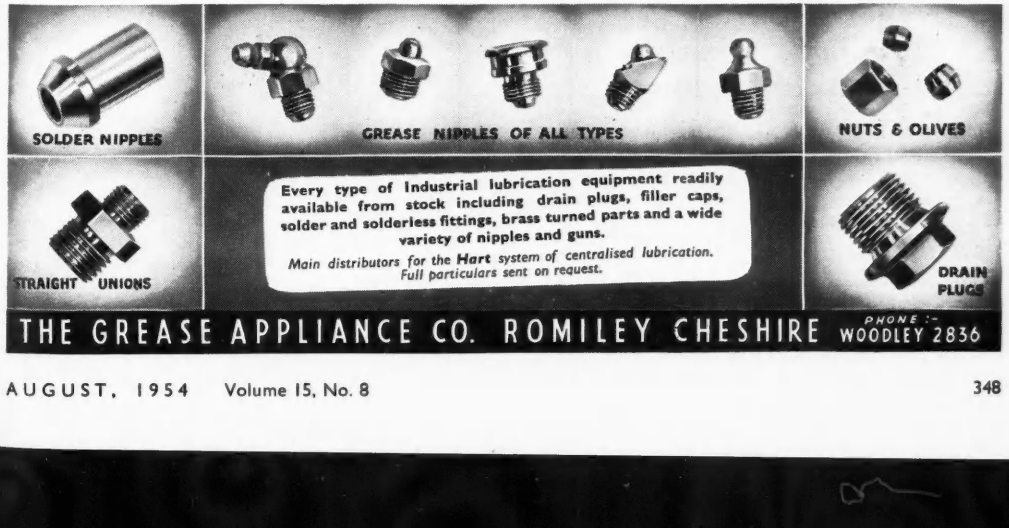
2.—(*a*) The provisions for the duty-free entry of machinery should continue to be operated by Government departments ;

(*b*) The responsible department should set up a consultative committee containing representatives of industry.

3. The duty-free entry of machinery should be by consignments and the field for applications should not be limited to specified classes of machinery.

4.—(*a*) The statutory provision for the remission of import duty on machinery should specify as the basic criterion for duty-free admission for non-procurability of similar machines in the United Kingdom ;

(*b*) The suitability of machines for the particular work for which they are required should be taken into account when applying the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test of similarity, provided that the applicant can establish that the machine is to be used to a very substantial extent for this special purpose.

5. The administering departments should see whether it is possible to apply somewhat flexible rules in cases where United Kingdom deliveries are protracted.

6. Duty-free provisions should be extended to plant, but applications should be scrutinized very closely.

7. The policy of the Board of Trade and Ministry of Supply on the remission of import duty on parts and accessories of machinery should be retained, subject to the application of our recommendation on the minimum value limit, and parts and accessories of plant should be dealt with similarly.

8. No change should be made in the department's policy of confining the duty-free licensing of machinery to machinery for productive industrial processes, and the same limitation should be applied to plant.

9. The applications eligible for consideration should be confined to consignments of similar or closely associated machines or plant where the value of the machinery or plant otherwise eligible for a duty-free licence required by the individual user is not less than £2,000.

10. Apart from any minimum limit of value which may be imposed, the administrative rules applied to applications should not be published.

Figures included in an Appendix to the report indicate that total imports of machinery into the United Kingdom for the financial year 1950-51, were valued at £42,800,000 and of this amount machinery exempt from duty accounted for £16,100,000. For 1951-52, the corresponding figures were £71,400,000 and £19,400,000 and for 1952-53, £110,800,000 and £15,700,000. It is pointed out that the totals for the two latter years were inflated by the Ministry of Supply imports in connection with the rearmament programme and that the duty concessions on those imports are not included in the "exempt" figures.

The number of applications for duty-free entry of machinery in 1950, was 5,948, in 1951, 12,313 and in 1952 (to March 15), it was at the annual rate of 15,549.

The value of Treasury licences remitting duty on imported machine tools (metal working and wood-working) in 1949, was £5,455,500, in 1950, £8,581,700, and in 1951, £9,325,000.

BUSINESS NOTES

The Industrial Products Division of Philips Electrical Ltd. announce the introduction of their new monthly publication "Philips Serving Science and Industry." This journal, similar in approach to "Philips Technical Review," will be devoted to new types of industrial equipment and industrial processes covering a wide field. Although emphasis will be laid on applied industrial electronics, articles dealing with new developments in Arc, Resistance Welding and Filtration will also be included.

The first issue contains 32 well illustrated pages dealing with the application of electronic instruments for measuring and recording vibration in power plants; the speeding up of woodwork production by means of Dielectric-loss Generators; A new installation for Water purification at Rotterdam; Different types of Oscilloscopes and their application, and a survey of the construction and application of the Electron Microscope.

"Philips Serving Science and Industry" is primarily directed to a technical audience, but many articles will be concerned with practical production problems of a widely differing nature which should prove of interest to industrial management.

The publication is distributed free of charge and though a substantial mailing list has already been built up, a limited number of applicants can still be accepted. Requests should be made to the Publication Department, Philips Electrical Ltd., Century House, Shaftesbury Avenue, London, W.C.2, on official notepaper and the position of the applicant should be stated.

John Brown & Co. Ltd., Sheffield, have acquired control of A. C. Wickman (Canada) Ltd., Queensway, Etobicoke, Toronto, Canada. The works include complete processing equipment for tungsten carbide, and extensive precision machine shops. **Mr. W. T. Muirhead** will be president, **Lord Aberconway,** chairman, and **Mr. Eric Mensforth,** managing director of Firth Brown Tools Ltd., Sheffield, deputy chairman of the company. The Board of Directors will include **Mr. L. C. West,** vice-president and assistant general manager, **Mr. L. B. Manning,** sales manager, **Mr. P. H. White,** works manager, and Mr. A. T. McCormick, secretary-treasurer.

The Canadian interests of John Brown & Co. Ltd. include First Brown Steels Ltd., whose president is **Mr. J. H. Cooney,** with offices and warehouses in Toronto and Montreal, and Firth Brown Tools (Canada) Ltd., whose president is **Mr. A. E. Steer,** which has just moved into newly constructed works at Galt, Ontario.

Crofts Engineers (Holdings) Ltd., Thornbury, Bradford, have acquired the share capital of J. Parkinson & Son Ltd., Shipley. The present directors, Mr. Edward Parkinson and Mr. Harry Parkinson will still control the company under the existing management.

The Industrial Drafting Co. Ltd., Design House, St. John's Road, Huddersfield, announce that they are now handling all products, including all types of Vernier gauges, manufactured by Instruments (Huddersfield) Ltd. for export to Canada, the United States and South Africa. They are also Agents for the sale of tungsten carbide plug gauges manufactured by Broomfield Engineering Co. Ltd., Marsh, Huddersfield.

Lloyds Craftsmen in Steel. F. H. Lloyd & Co., Ltd., James Bridge Steel Works, Wednesbury, have published a lavishly illustrated 44-page brochure in which tribute is paid to the British

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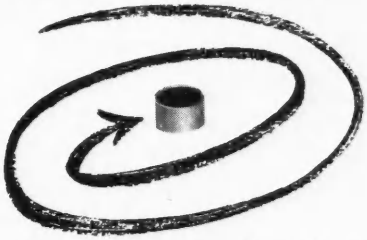

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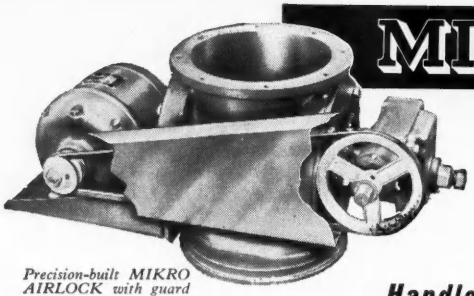

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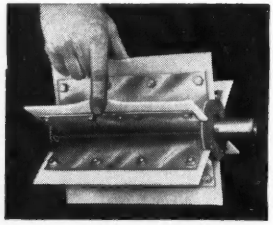

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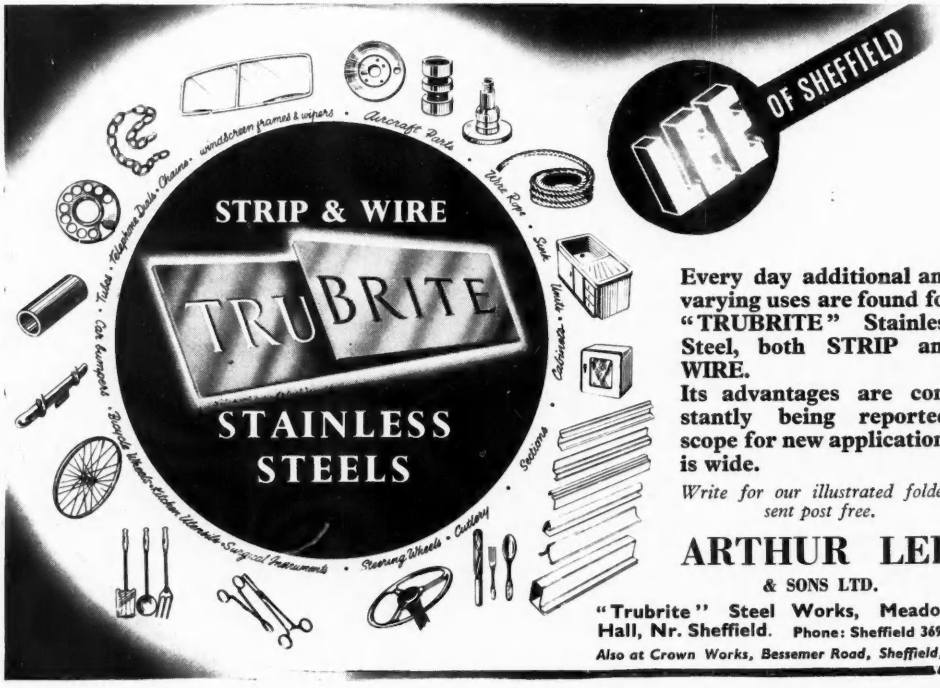

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craftsman, his inherited skill and his pride in good workmanship. Many of the illustrations and the accompanying descriptions emphasise the important role which craftsmen, such as pattern-makers, moulders and coremakers, melting plant crattsmen, fettlers, inspectors, etc., play even in the most modern foundry. Special sections deal with the machining of castings, heat treatment and maintenance. Excellent illustrations show a great variety of castings manufactured at the James Bridge Steel Works for some of Britain's leading engineering concerns.

Ironworks Extensions at the Appleby-Frodingham Steel Company Scunthorpe. This £15 million project was formally opened at Scunthorpe on 29th July by Sir Archibald Forbes, chairman of the Iron & Steel Board. By pulling one lever Sir Archibald started up the sinter plant and lit the "Queen Victoria" blast furnace, the largest in Europe.

The "Seraphim" plant, which consists of two huge blast furnaces ("Queen Anne" and "Queen Victoria") and ancillary ore-preparation and sinter plant, is expected to boost the Works' production of pig iron by 600,000 tons per annum. When some older furnaces have then been taken out of commission Appleby-Frodingham will produce 1,400,000 tons per year.

The project is the result of 10 years of research which sought an answer to the deteriorating quality of the local lean iron ores. With the new processes that have been installed, better, cheaper and larger quantities of iron will be produced, so ensuring hte continuation of ironmaking in Scunthorpe for many years to come.

BRITISH STANDARDS

Copies of British Standards may be obtained from the British Standards Institution, 2, Park Street, London, W.1.)

Fire Hose and Suction Hose Couplings, Branch Pipe and Nozzle Connections. B.S. 336 : 1954 applies to the following :—

(a) Delivery hose couplings and connectors of the instantaneous pattern :
  (i) Hose couplings with ribbed and multi-serrated tails for 1½, 1¾, 2, 2½, 2½, 2¾, 3 and 3½ in. hose.
  (ii) Single lug twist release connector.
(b) Suction hose couplings for 3, 3½, 4, 4½, 5, 5½ and 6 in. hose.
(c) Branch pipe and nozzle connections.

In preparing this revised standard, account has been taken of present trends and practices and various modifications and additions have been made. These include the introduction of an instantaneous connector with twist release, and a material clause which provides for the use of both copper alloys and aluminium alloys. This standard also provides for both ribbed type tail pieces and multi-serrated type tail pieces.

The standard size of coupling adopted is that known hitherto as the "2½ in. gauge."

The design of the suction hose couplings has been modified and now provides for an external locking ring instead of an internally screwed sleeve. For suction couplings, a two-ribbed type of tail end has been introduced in place of the serrated type. A slight modification has also been made to the branch pipe in that a shroud has been provided to ensure that the washer is adequately retained in position.

The following items which appeared in the 1936 edition have been excluded from this revised standard :—

(a) "V" and Round thread delivery couplings. These have been generally superseded by the instantaneous pattern.
(b) Screwed outlets of hydrants. These are now covered by B.S. 750, "Underground fire hydrants and dimensions of surface box openings."
(c) Types A, B and C threads for branch pipe and nozzle connections. A single type of thread, namely, the 1¾ B.S.P. Whitworth thread has been adopted for these connections. Price 4/-.

Gear Hobbing Machines for Turbines and Similar Drives. B.S. 1498 : 1954. The drafting of this specification was undertaken in the first instance at the request of the Admiralty for the purpose of establishing standards of accuracy for gear hobbing machines intended for the production of high grade gears for turbines and similar drives. The standard introduces a number of amendments in detail which have been found desirable as the result of experience in its use. The two grades of accuracy originally specified are maintained : Grade A for machines capable of producing gears for relatively heavy loads with high pitch line velocity, and Grade B for machines suitable for producing high quality gears for normal loads and pitch line velocities.

The text has been revised and the sections re-arranged in a more logical sequence, and a chart showing maximum permissible transverse pitch errors, based on the formulae given in the text, has been added. Price 4/-.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

APPOINTMENTS VACANT

ELECTRONIC ENGINEER. Applications are invited from men preferably between 28 and 35 years of age, for an appointment with a large firm in connection with applied nuclear energy engineering research and development. Applicants must have an honours degree in electrical engineering with experience in light electrical engineering and/or electronics with about six years' experience in industry, and be familiar with or have a working knowledge of electric control gear and instrumentation. A knowledge of servo mechanisms and their application would be an advantage but is not essential. Salary would be comparable with that paid by the Civil Service, London rate, the grading depending on age and experience. Apply in the first instance to Box No. 123.

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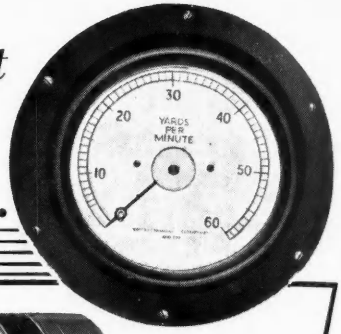

The illustrated units are the only two items necessary for the electrical measurement of speed. Thus, the Indicator can be mounted at any distance from the machine and any specified number of Indicators can be connected to one Alternator.

Alternators available with a choice of six drives; Indicators for either flush or projecting mounting in dial sizes 4″, 6″ or 8″.

Enquiries are welcomed and specifications will be forwarded on request.

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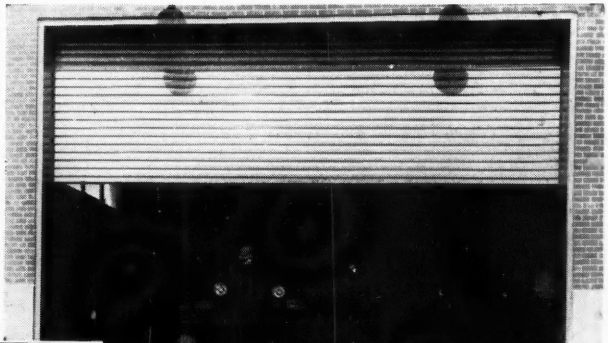

These weatherproof shutters are part of an installation in a province of Canada which experiences extreme climatic conditions. The sturdy construction and specially designed laths combine to defeat the weather at its worst, and at the same time prevent unauthorised intrusion. Both electric and hand-operated models are available and there's a fireproof variety, too.

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BOOKS RECEIVED

A Treatise on Applied Hydraulics. 4th Edition, 1954. By Herbert Addison, O.B.E., M.Sc., M.I.C.E., M.I.Mech.E. 732 pp., 494 illustrations. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 56/-.

Since the first edition of this book was prepared, twenty years ago, the art of hydraulic engineering and the sciences upon which it depends have alike made uninterrupted progress. These advances—advances in the design and construction of hydraulic machines and hydraulic structures—have been recorded in numerous specialised technical books and papers. Nevertheless, this extension of knowledge has not lessened the need for a general book, such as this one. On the contrary, students and engineers should welcome a textbook which limits itself to direct explanations of hydraulic principles, while serving at the same time as a guide to sources of more detailed information.

In the present edition, therefore, little change has been made in the style of presentation. The subject matter has, however, been carefully revised and covers a very wide field indeed. Only one specifically new section has been introduced. This is a brief collection of biographical notes on some of the outstanding personalities whose efforts have done so much for the advancement of Hydraulics.

This book epitomises the author's experience in the lecture room and laboratory during thirty years of instruction and research.

An Introduction to Cost Accountancy—Vol. I. By R. Warwick Dobson, C.A., F.C.W.A. 320 pp., 17 illustrations. Publishers: Gee and Company (Publishers) Limited, 27-28 Basinghall Street, London, E.C.2. Price: 35/- (Postage 7d.).

While accountants who have taken an active part in the rapid development of cost accountancy during the last twenty years have extended their knowledge, and while certain of them have written books dealing with particular aspects, no book has been written in Great Britain dealing, as a whole, with cost accountancy in its present stage of development.

The present work has been written to fill this gap. It deals in an introductory way with all the subjects which are at present within the sphere of cost accountancy; it does not, however, attempt to tell the cost accountant the meaning of the information he prepares. The book is constructed on entirely new principles, and presents the essentials of the subject in easily assimilated chapters. The terminology of cost accountancy has been incorporated in the text.

The book is divided into three volumes, of which this (Vol. I) deals with "Costing and Cost Control." Vol. II covers "The Elements of Cost Accounting," and Vol. III is entitled "Cost Recording and Presentation."

Principles of Mass and Flow Production. By Frank G. Woollard, M.B.E., M.I.Mech.E., M.I.Prod.E. 196 pp., 102 illustrations. Publishers: Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price: 25/- (Postage 8d.).

The author has had some thirty years experience of mass- and flow-production engineering. Out of this wide and unusual experience has grown the philosophy set down in these pages. After defining the terms "mass production" and "flow production," the author briefly traces the history of this type of manufacture. He then lays down a series of eighteen basic principles relating to the setting up of a flow-production plant, and considers the implication of each in considerable detail.

Flow production is frequently thought of as being suitable only for large and highly organised enterprises. The author stresses, however, that its methods can be applied with the same benefits to small quantities in small firms, and that large capital is not essential to their introduction. As Sir Leonard Lord, K.B.E., says in his foreword, the book "offers encouragement to the little firms to adopt the flow system wherever this is possible . . . and it is possible far more often than is generally believed."

The principles and methods described are suitable for the manufacture of almost every article that is readily and continuously saleable (or can be made so by skilful marketing), and production executives in a very wide range of industries, as well as all students of engineering economics, will find this book, which has been published for "Mechanical Handling," of great interest. Throughout, the text is amplified by photographs and diagrams of significant examples from the Britain, the U.S.A., and Europe.

Memorandum on Gamma-Ray Sources for Radiography. 2nd Edition, 1954. 28 pp., 11 illustrations. Publishers: The Institute of Physics, 47 Belgrave Square, London, S.W.1. Price: 3/6.

This memorandum is the second edition of one which was first published in 1952. The subject matter has been brought up-to-date and has been extended in many respects, particularly as regards the number of radioactive materials receiving consideration. The preparation has again been in the hands of a Committee of the Non-Destructive Testing Group (formerly the Industrial Radiology Group) of the Institute of Physics, and the intention has been to provide a brief statement on gamma-ray sources for radiography, particular reference being made to the products of the Atomic Energy Research Establishment at Harwell, and the Radiochemical Centre at Amersham.

By means of these sources, a wide variety of useful radiography can be carried out, without the need for X-ray equipment. This is fully realisable only if radioactive materials are appreciated, and this memorandum summarises such information as is of importance in industrial radiography. Attention is also given to radiographic technique, protection of personnel, and the costs involved. An appendix is included, in which summaries of much of the information are given.

Engineering Contracts and Specifications. 3rd Edition, 1954. By Robert W. Abbett. 446 pp. Publishers: John Wiley & Sons, Inc., New York, and Chapman & Hall, Ltd., 37 Essex Street, London, W.C.2. Price: 48/-.

This book, which is a basic legal guide to the administration of constructional work, gives a clear and concise description of the fundamental methods of preparing contracts and specifications, together with the applicable principles of law pertaining to engineering and construction.

The present edition follows the same scope and arrangement as previous editions. However, the text has been revised and expanded throughout. The chapters on cost-plus-fixed-fee contracts and contracts for engineering and architectural services have been completely rewritten and enlarged, in accordance with current professional practice. The chapters on specification writing have been rearranged, and one new chapter has been added.

As in the past, emphasis is on *how* to write contracts and specifications, rather than merely *what* to write. The approach is strictly that of the professional engineer, and the book includes many of the ways in which contracts procedure of the U.S. Government differs from that of private practice. This book makes an excellent reference source for engineers, architects, contractors, and all those who are interested in the fundamental legal aspects of construction.

What Every Engineer Should Know About Rubber. By W. J. S. Naunton, M.A.(Cantab.), M.Sc., Ph.D.(London), Dip: Chem.(Munich), F.R.I.C. 126 pp., 145 illustrations. Publishers. The British Rubber Development Board, Market Buildings, Mark Lane, London, E.C.3. Price: 3/6 (post paid).

The unique properties of rubber make it a valuable material for numerous engineering applications but, while the engineer is usually fully conversant with the properties and uses of the various metals he has to employ, he is frequently not so well versed in the characteristics and applications of rubber. The purpose of this book is to provide the necessary information to enable the engineer to make effective use of rubber.

The author was formerly in charge of the Rubber Laboratories of Imperial Chemical Industries Ltd., and during World War II much research and development work for the Services was conducted in these laboratories. In the course of his work, the author had many contacts with engineers, and this has enabled him to cover the subject from the point of view of the engineer who wishes to incorporate rubber in his designs.

Over half the book is devoted to specific engineering uses of rubber. In the remainder, the sources, properties, manufacture, and testing of rubber are covered. A useful index is also included.

This handy volume, attractively produced and lavishly illustrated, is worthy of a place on every engineer's bookshelf, setting out, as it does, the virtues and defects of what is virtually an indispensable material.

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These rings are also available in extremely small sizes, which are especially suitable for the electrical and precision-instrument industries.

3. Mechanical Handling Equipment. In a neatly conceived and produced illustrated catalogue of 40 pages, specifications are given of a representative selection of lifting and conveying equipment suitable for a wide range of applications in many industries.

The equipment presented embraces vertical transport by means of electric lifts of modern design and transporter cranes for goods receiving and despatch, together with comprehensive equipment for internal transport of materials.

4. Pressings. An extremely well produced and illustrated 40-page brochure in a loose-leaf binding reviews some of the activities of a company which has been engaged for many years in the manufacture of light and heavy chassis frames, axle casings, etc. The works of this company are equipped with the most modern plant, which includes some of the largest mechanical and hydraulic presses in Great Britain. Some of this equipment, together with examples of the products manufactured, is strikingly illustrated in this publication.

5. Non-Ferrous Alloys. In a new and enlarged edition of a brochure issued by a company with one of the best equipped non-ferrous foundries in the world, details are given of a wide range of non-ferrous products, including phosphor-bronze alloys, lead bronze, manganese bronze, alloy castings, centrifugal castings, corrosion- and acid-resistant alloys, anti-friction metals, and bearings of various kinds.

The brochure, which comprises about 50 pages and is lavishly illustrated, depicts many of the facilities of the company, together with a representative selection of their products.

6. Resilient Flexible Couplings. Details of a comprehensive range of resilient couplings with a wide variety of applications are contained in a series of leaflets and pamphlets. The range includes a "self-supporting" shaft coupling, which has been designed to eliminate an adjacent bearing. This type of coupling is being used on heavy lift gear, paper-machinery drives, and similar arduous applications.

Another coupling in the range is an equaliser or compensating type, which is of particular use in dredger-bucket shaft drives or machines of a similar nature. There is also a self-aligning coupling, which embodies the main features of gear-type couplings, plus refinements which are claimed to lead to longer life and easy replacement of worn parts.

7. Metal Spraying. An excellently produced and illustrated book of 34 pages describes a wire process of metal spraying. The system is such that any metal which can be drawn into wire and melted in an oxy-hydrogen blowpipe may be sprayed and, in this connection, the book lists numerous sprayable metals, together with their applications.

Other subjects dealt with in this interesting publication include coatings, thickness and quality control, preparation of surfaces for metal spraying, building up of worn parts, research, and the theory of metal spraying.

8. Ring Springs. Details are given in a 4-page leaflet of a type of spring which consists of outer and inner rings, each ring co-acting with the adjacent ring along conical surfaces. When axial pressure is applied, the outer rings expand, the inner rings compress, and each conical surface telescopes into the adjacent one a certain distance in the axial direction. No torsion takes place, and the travel between each pair of conical surfaces forms the total travel or stroke of the spring.

Some advantages claimed for this type of spring over other types include higher capacity, longer life, and saving in maintenance and repair. Furthermore, they absorb 70% of the energy of recoil and their construction is such that the column of spring elements lends itself to simplified design in a wide range of applications.

9. Multi-Purpose Machine for Finishing Operations. Details are contained in a 4-page leaflet of a versatile and economical machine designed to perform the maximum number of different finishing operations.

To meet various needs, a wide range of interchangeable attachments is available, enabling a large number of operations to be effected easily and efficiently, including general grinding and polishing; fettling of castings and forgings; chamfering of holes; wood sanding, routing, drilling, etc.; de-scaling and rust removal; de-burring of pressings and machined parts; and de-flashing of plastic mouldings.

The machine is designed to take bands of 48-60 in. × 2 in., or 48 in. × 2 in. in width. The main column of the machine may be used in either the horizontal or vertical positions, change-over being very quickly and easily effected.

10. Aluminium Alloy Ingots. In a neatly produced 40-page catalogue, detailed specifications of and technical data on aluminium alloy ingots are presented. The alloys covered are those listed in B.S.S. 1490, starting with L.M.1, together with four other special-purpose alloys outside this range.

This catalogue provides a fund of useful information and is at the same time a simplified form of reference to requirements in the field of aluminium-alloy ingots.

11. Industrial Stethoscope. Details are contained in an interesting brochure of an industrial stethoscope which has no diaphragm, is non-electric, and is extremely sensitive to all frequencies between 20 and 7000 cps. When exploring an area under inspection, the operator merely adjusts a conveniently located frequency-regulator knob until signals are coming in at full strength. This exclusive principle enables all extraneous noises to be tuned out.

The instrument, which is supplied with its accessories in a strong, lightweight case, has a wide range of applications, including the tracing of knocks, squeaks, etc., checking of welded joints, testing of the brushes, bearings, etc. of electrical equipment, checking of tooth wear of gears, tracing air and gas leaks, etc.

12. Tappers and Accessories. Details are contained in a leaflet of a range of tappers which are thoroughly practical, soundly designed, and built to withstand the roughest usage. One tap only is required in the Whitworth threads for each size up to 1½ in. Above this size, two taps are necessary. For gas threads, one tap only is required for any diameter. Taps are supplied for all sizes and threads in carbon cut thread and high-speed ground thread.

The tapper, which is made in four sizes, can be used in any drilling machine fitted with a reversing motion.

13. Swarf Crushers. A machine, designed to reduce swarf or similar bushy turnings to short lengths suitable for shovel handling and easy storage, is described in a 4-page brochure. The crusher is made in six sizes, with capacities between 7 cwt and 7 tons per hour, when reducing brittle steel turnings, and consists of a rotor enclosed in cast-iron and steel frames, with renewable chilled-iron liners. The rotor hammers are loosely attached and swing on pins. These hammers are of steel, suitably tipped, the tips being renewable.

The mechanical feeder, stated to be the only one available for a swarf crusher, consists of three bolted sections, together with motor, starter, and drive. Its operation is such that the masses of swarf are teased out in a long stream and are under control almost to the crusher hammers.

14. Powered Straightener. Details are contained in a leaflet of a powered stock-straightener with many important features, including quick-action "alligator" opening, to permit the feeding of coil without alteration to roll settings. Furthermore, the pinch and lower straightening rolls are powered, with all rolls running in needle bearings.

The maximum coil width with this machine is 6 in., the maximum thickness (steel) is 0·062 in., and the feed is infinitely variable between 250 and 1000 inches per minute.

15. Precision Indicator Gauges. A well presented 16-page booklet describes and illustrates a range of pillar- and bench-model precision indicator gauges, designed to carry out most inspection requirements.

These gauges (magnification = × 200) are rigidly and robustly constructed for long, trouble-free service, and can be supplied with a wide range of scales, calibrated in inches or millimetres, to suit requirements. These large, clear scales, with their prominent limit pointers, reduce risk of error.

16. Low-Loss Cores and Micropowder Magnets. A well produced 14-page publication gives full technical specifications and describes, with coloured flow sheets, the production and use of a range of low-loss cores and micropowder magnets. Graphs are included, showing the performance of these items under varying conditions, together with a section describing suitable designs of low-loss cores and magnets for various applications. The publication also includes comparisons with other materials, and gives details regarding stability.

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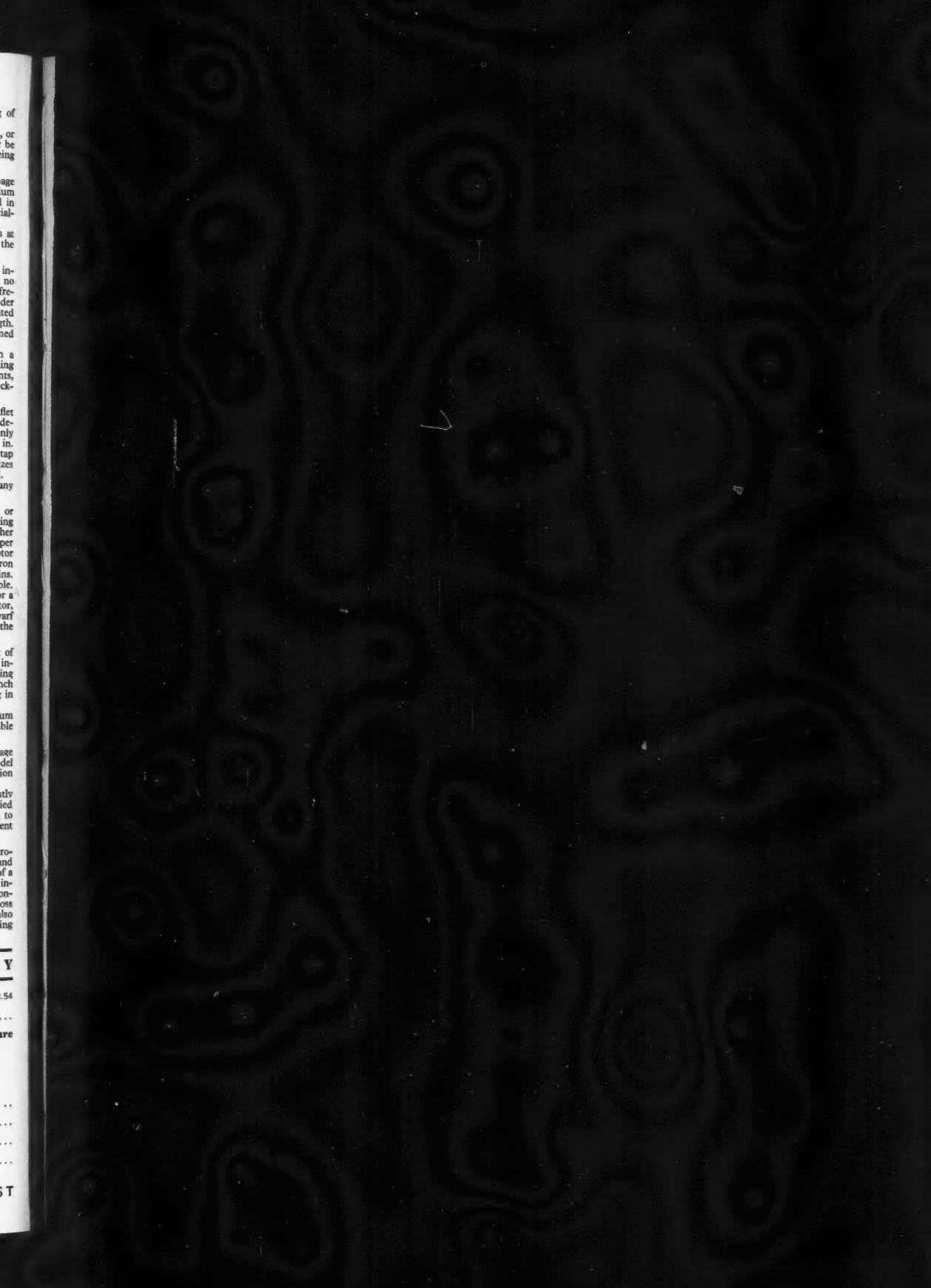

THE BLUE PAGES

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● *LEAD PLATING OF ALUMINIUM*

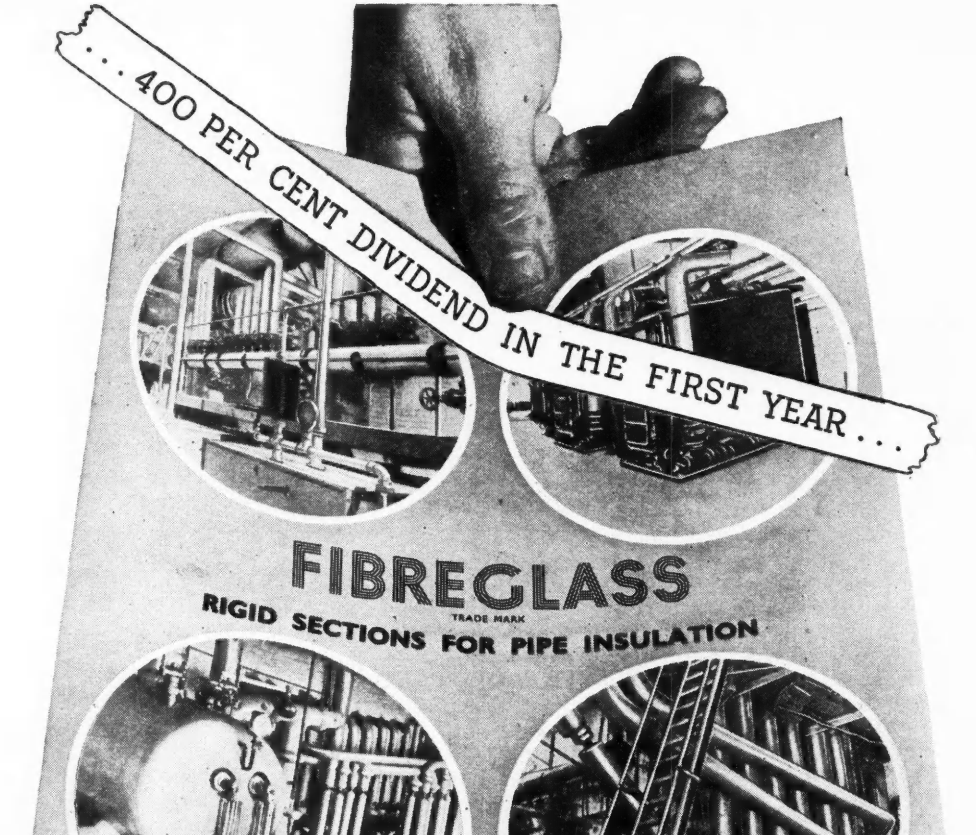
The direct lead electroplating of aluminium and aluminium alloys in a conventional electroplating bath cannot be carried out successfully, as the resultant plating contains blisters and is not sufficiently adherent. Unfortunately, the various forms of treatment, such as zinc or iron plating, which are usually employed before the electroplating of aluminium with other metals, are not suitable for use prior to lead plating. The reason for this is that zinc and iron are attacked by the usual lead-plating baths and therefore do not protect the aluminium from the corrosive action of the electrolyte. This results in the formation of blisters in the lead plating. It has therefore been proposed to carry out the electrodeposition of lead upon a nickel plating previously formed on the aluminium by electrolysis; however, in the most recent modification, the layer of nickel is chemically deposited. Contrary to expectation, the lead deposit is perfectly adherent and is free from blisters, while its thickness may vary from a few microns up to several millimetres. Before treatment, the aluminium or aluminium-alloy articles to be lead-plated are pickled, in order to form on the surfaces of the article roughnesses which, in the plating stage, facilitate the adherence of the lead. The articles are then treated with an acid solution containing a nickel salt capable of giving a deposit of nickel through chemical reaction with the aluminium. Electroplating is then effected in a bath of the usual type, containing a lead salt, such as lead perchlorate, lead fluoborate, or lead fluosilicate.

● *NEW EXCITATION SYSTEM FOR TURBO-ALTERNATOR PLANT*

An interesting new excitation system for large turbo-alternator plant dispenses with the brushes, commutator, and armature windings used in the conventional type of d.c. exciter. In the new system, power for excitation is generated at high frequency by an inductor generator, and the a.c. generated is then rectified by a bank of selenium rectifiers. The inductor generator is thus the only piece of equipment with moving parts and, since its rotor carries no windings, maintenance is practically negligible, compared with that required with exciters of conventional design. The inductor alternator, which in one specific instance has a frequency of 360 cycles per second, is controlled by magnetic amplifiers responsive to the main alternator terminal voltage. Inductor alternators, which at higher frequencies are widely used for induction heating plant, are known to have inherently high reactance and are particularly sensitive to lagging power factor load. The speed of response of a system of this kind is said to be very high. It is claimed that perhaps the most interesting advantage of the new development is that it eliminates two major causes of turbo-alternator outage, i.e., exciter commutator maintenance and brush replacement. However, it remains to be seen whether the use of a static rectifier and magnetic amplifier does not also represent a source of potential trouble. It would also appear that the generating efficiency of the new type of exciter plant is lower than that of the conventional type of d.c. generator.

● *FATIGUE STRENGTH OF GEAR TEETH*

Fatigue tests on many machine elements have shown an endurance limit for steel at a stress level corresponding to a life of 10 million cycles. To run tests for more than 10 million cycles is expensive, and few laboratories have carried out large-scale test programmes involving such long runs on gears. For this reason, data relating to the endurance limit for gears are sparse. Much of the fatigue data published on machine elements other than gears show a straight-line relationship on a log-log scale, and gear test data have likewise been expressed by a straight line in the SN diagrams. It has, however, been found that tests of spur-gear teeth show that the true diagram follows a characteristic pattern which is divided into three regions. The first of these, covering the range from 1 to 1000 cycles, shows a very slight slope, while in the second region, from 1000 to 300,000 cycles, a steeply sloping characteristic is observed; finally, in the third region, from 300,000 to 1000 million cycles, the slope is again very slight. In the steep-slope region, a tenfold increase in cycles will drop the load capacity by about 35%. Beyond one million cycles, the drop in capacity is less than 10% when the cycles are increased tenfold. Recent tests have shown that in a pinion-tooth test, comparing shot-peened teeth with teeth not thus treated, extending over 200 million cycles, there was no evidence of a steep slope in the region beyond one million cycles. Shot-peening of some of the teeth of a



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pinion showed those peened to be about 35% stronger. In this case, shot-peening was done by hand. Pinions peened by machine have shown gains in strength as high as 40%.

● *STRESS MEASUREMENT IN COATINGS AND FILMS*

A new instrument has been developed for the measurement of tensile or compressive stresses in chemically deposited metals and electroplated metals, as well as in films of paint, lacquer, and plastic. It is reported that this interesting device is capable of indicating stresses ranging between 100,000 psi in tension and 50,000 psi in compression. The stress-indicating mechanism is actuated by the deflection of a flat metal disc which dishes in or bulges out, according to the shrinkage or expansion of the coating deposited on the outside of the disc. The small amount of deflection prevailing at the centre of the disc is magnified by a hydraulic arrangement to such an extent that a deflection in thousandths of an inch can be read in inches on a linear stress scale. The instrument can, for instance, be used directly in a plating bath for control purposes, or it can be installed for research in a separate tank, for correlating such factors as atomic structure, current density, pH, and temperature with the magnitude of stress produced. The stress readings may be taken continuously as a function of time, or they may be recorded individually in connection with readings of the thickness of the deposit under test. When working with paint, lacquer, or plastic films, it is possible to follow the curing of the material by the indication of the instrument. The device is being produced in a high-temperature plastic for use with electroplated and chemically deposited metals; for such applications as the testing of paint, lacquer, and plastic films, it is made of metal.

● *NEW FLUX FOR SOLDERING ALUMINIUM*

It is well known that aluminium is difficult to solder, owing to the presence of a tenacious skin of oxide on atmosphere-exposed surfaces. The conventional fluxes used for lead-tin solders on brass or steel cannot be employed on aluminium. Moreover, the lead-tin solders, if brought into contact with aluminium, set up galvanic junctions which cause the aluminium next to the joint to corrode in the presence of a moist atmosphere. It is claimed that this difficulty is now eliminated by the application of a new type of flux to be used in conjunction with zinc-tin or zinc-aluminium solders. The flux is said to be non-hygroscopic, so that it can be left in an open container for extended periods without any effect on its fluxing ability. The flux is in the form of a dry powder which melts at 380° F and becomes active at about 680° F. As it is a reaction flux with a stannous chloride base, it reacts with the aluminium oxide and with the underlying aluminium, so that metallic tin is deposited on the aluminium surface and aluminium chloride is formed. The latter volatilises and leaves no corrosive residue. Furthermore, if an excess of flux has been applied and has not decomposed, the excess can easily be washed away with water. The tin deposited on the aluminium surface temporarily prevents the formation of a new layer of aluminium oxide and then alloys readily with both the aluminium and the solder. Zinc-tin alloys with from 20% to 90% of tin, and zinc-aluminium alloys with about 5% of aluminium are reported to make satisfactory joints when applied with this flux.

● *MEASUREMENT OF METAL CORROSION*

A new technique has been developed which makes it especially easy to determine the extent to which a metal has been corroded. This technique is based on the electrical resistance method, which utilises the fact that metals and alloys have much lower specific electrical resistances than their corrosion products. Since the electrical resistance of a metal depends on its cross-sectional area, a decrease in thickness of a specimen due to corrosion may therefore be evaluated quantitatively from the increase in resistance. The principal advantages of this method are naturally derived from the fact that cleaning of the specimen is not required. This is an important feature, since cleaning methods are cumbersome and may lead to serious errors, especially if the amount of corrosion is small. At the same time, the electrical resistance method is capable of very high sensitivity. Thus, with the instrument used in carrying out the new technique, a decrease in metal thickness of the order of 0·2 to 0·4 micro-inches can be detected on a specimen of 0·001 in. in thickness. This sensitivity is of obvious advantage when the corrosion rate is very low. If, as in the case of alloys, selective oxidation occurs, corrosion determinations obtained by gravimetric methods are of doubtful value; however, an examination by means of the electrical resistance method may prove of more practical significance, because both electrical resistance and strength of the specimen depend upon the residual metallic core. Nevertheless, pitting cannot be evaluated by this method, and in cases of extreme non-uniformity, the change of resistance of the specimen will depend on the geometrical distribution of the pits.

● *ABRASIVE CHARACTERISTICS OF ALUMINA PARTICLES*

A recent investigation of the abrasive characteristics of both commercial and experimental aluminas was conducted with a view to determining whether they could be produced in several intermediate degrees of abrasive action. The equipment used was patterned after the Ridgway, Ballard, and Bailey impact abrasion hardness tester. In the impact abrasion method, a given weight of abrasive is picked up by a dry

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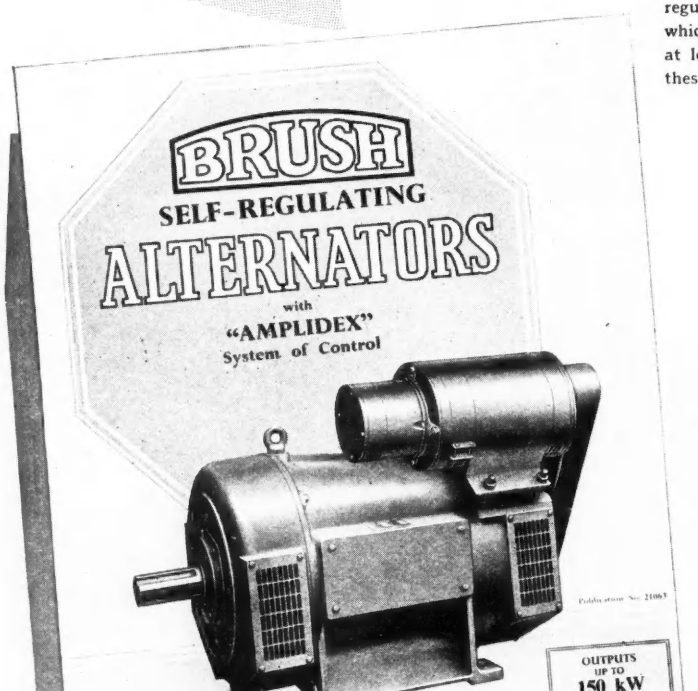

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air stream of high velocity and hurled against a flat plate (aluminium sheet or glass), and the loss in weight of the plate is then measured. It was found that the air-jet impact method gives reasonable and reproducible measures of the abrasive action of alumina grains. A hard, brittle material such as plate glass loses a considerable amount of weight when subjected to the abrasive action of the highly calcined aluminas; also, cutting action decreases markedly with a relatively small decrease in the calcination of the alumina. With the hard abrasive particles, size has little influence on the weight loss of the glass specimen. The abrasive cutting action of a series of calcined aluminas can be correlated with their ultimate particle size, the materials of largest ultimate particle size having the highest cutting action. A wide variety of abrasive action can be obtained with various grades of alumina. The most highly sintered aluminas lead to weight losses comparable with those of silicon carbide and commercial fused aluminas. Several structural materials were found to show essentially the same losses in volume during abrasion; however, in a series of aluminium alloys, a tendency was noted for the materials of lower strengths to have a higher abrasion resistance.

● *WASHER FOR ACCURATE PRELOADING OF BOLTS*

A very ingenious two-part washer has been invented and is already being applied in the aircraft industries, thus making possible the accurate preloading of bolts in a particularly simple manner. Exhaustive tests conducted with the washer are said to have shown that it can be designed to ensure an average tension preload of 80% of the desired bolt preload, with only slight deviations. It is expected that this will result in a sharp increase in the fatigue life of the bolts. The new washers are already in use on aircraft to join the lower half of the nose section to the fuselage, to join wing and fuselage, and for wing attachment. The new washer consists of two concentric metal rings, of which the thicker inner ring first takes the load when the bolt is tightened. Continued tightening then causes the outer ring to bind when the desired preload is reached. The point at which this binding occurs can be controlled by appropriate choice of washer dimensions and materials. During the tightening operation the operator " wiggles " the outer ring by means of a handle which can be discarded after it has served its purpose. It is claimed that this very simple method, which relies on the compressive properties of the washer, is greatly superior to the older method of preloading the bolt by means of a torque wrench. Close control of the compressive characteristics of the washer would appear to be most essential, since even small deviations from normal must inevitably lead to corresponding errors in bolt loading.

● *NEW HARDENING TECHNIQUE*

The last twenty years have witnessed the introduction of valuable new processes for the heat treatment of steel, among which isothermal hardening, martempering, and austempering are of outstanding importance. Each of these processes gives the metal a characteristic microstructure and set of mechanical properties. It is now reported that to this list has been added a new method which appears to be especially suitable for use in the manufacture of wire or strip. It is stated that not only do good mechanical properties result, but that these properties are usually superior to those obtained by conventional methods. The new method of steel hardening differs from usual methods in that the formation of martensite or bainite takes place from a deformed austenitic structure. The treatment is carried out at a heat below the recrystallisation temperature and may therefore be called " cold working," although the metal is still at a temperature at which it is by no means cold to the touch. In the new process, the steel is first brought into the metastable austenitic condition in which it is worked to its final shape. Subsequent transformation of the metastable cold-worked austenite into the bainite or martensitic microstructure then results in a steel with outstanding mechanical properties. The nature and quality of these properties depend on the degree of cold work to which the material was subjected prior to the transformation of the austenitic structure. For this reason, deformation should be carried out below the recrystallisation temperature and should be nearly completed when the transformation of the austenite commences.

● *RECORDING FLUXMETER*

The use of ballistic galvanometers for obtaining hysteresis loops of magnetic materials may now be said to be outmoded by the recent development of a recording fluxmeter for tracing d.c. magnetisation curves. This instrument represents an improvement upon a similar type developed a few years ago which employs one or two integrators and a two-axis recorder for tracing B-H curves directly on standard co-ordinate paper. A particular advantage of the instrument is that the search coil to be wound on the sample requires only a few turns of wire, owing to the sensitivity of the instrument. The principle of operation of the fluxmeter is as follows :—Two coils are wound on a ring sample of the magnetic material to be investigated. The primary coil is excited with slowly varying direct current, resulting in a voltage drop across a ballast resistor, which causes the movement of the recorder pen in the X-axis direction; this movement is therefore proportional to the current in the primary coil and consequently to the magnetising force. Any variation in the magnetic flux in the sample will induce a voltage in the secondary coil, causing deflection of a

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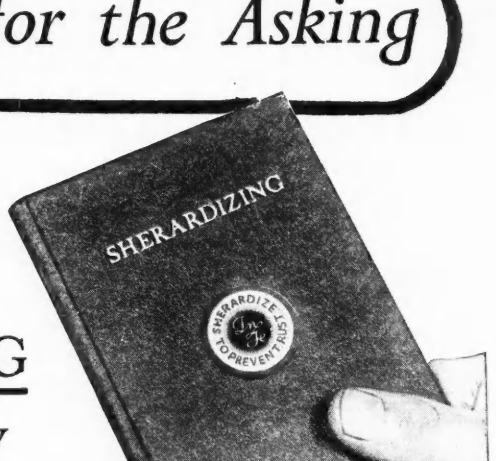

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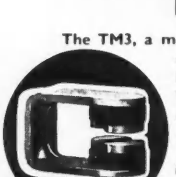

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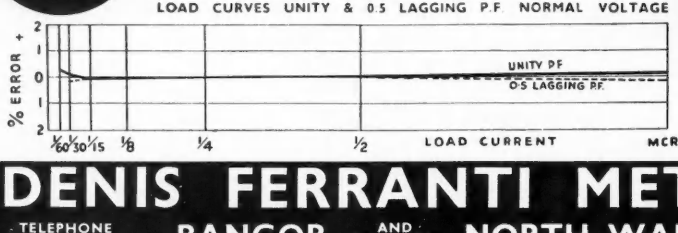

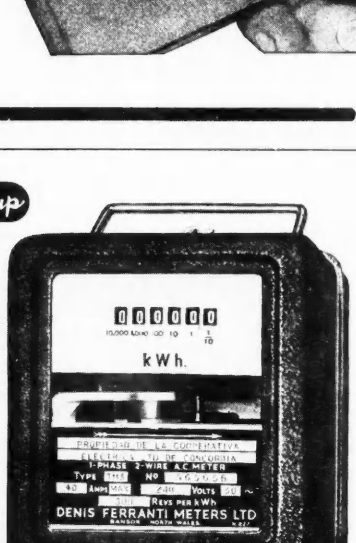

Illustration shows metal-cased meter with cyclometer register. Pointer registers and moulded cases can be supplied.

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galvanometer. The mirror of the galvanometer, which was previously illuminating two phototubes equally, will then direct more light onto one phototube than onto the other and will thus generate an error voltage in the bridge circuit of which the phototubes form part. This error voltage is amplified and fed back into the galvanometer circuit, to reduce the galvanometer deflection. The output of the amplifier, which is the integral of the voltage induced in the secondary coil and is thus proportional to the flux in the sample, is applied to the Y-axis of the recorder.

● *NEW CASTING TECHNIQUE*

In casting technique it has long been practice to utilise moulds with so-called feed heads or hot taps. These feed heads serve as a reservoir of liquid metal, which will flow into the casting in the mould, to fill up any cavities or voids in the metal caused by shrinkage during cooling and solidification. For this purpose, the material in the feed heat must remain liquid after the main body of material in the mould has been frozen. This can be achieved by various means, including heating. A recent invention envisages freezing the metal in the uppermost part of the feed head as quickly as possible, while the liquid metal in the lower part of the head is maintained at as high a temperature as possible. It is claimed that this method is particularly effective in the case of large feeding heads on castings or ingots, where the ratio of the vertical height to the cross-section is considerable. One possible explanation is that, in an alloy such as steel, the first crystals to form are richer in iron than the original liquid. The liquid in which these crystals grow is thus deprived of iron and therefore becomes richer in other alloying constituents, such as carbon and phosphorus, reducing the freezing temperature of the liquid. The liquid of lower freezing temperature, which sinks from the solids formed by the chill or chills in the top of the head, owing to the contraction caused by the freezing as a whole, remains in the lower part of the head and freezes later than the liquid in the mould itself. In this way liquid remains available in the lower part of the feed head to fill up cavities or voids in the ingot caused by contraction.

● *NOVEL DESIGN OF THERMIONIC VACUUM TUBE*

With a view to the elimination of such shortcomings as liability to failure from vibration and shock, a manufacturer of thermionic vacuum tubes has undertaken a radical re-design of his products. The design evolved is characterised by the use of a ceramic envelope or cap, made of aluminium oxide, in which the various component parts of the tube are stacked one on top of the other in the assembly process. This, of course, is a procedure quite different from conventional manufacturing technique. Another interesting feature is the use of ceramic spacers in place of mica spacers, and it is claimed that not only are the performance and service reliability increased by these innovations, but the possibility of mass production is also enhanced, owing to the inherent simplicity of design. Although the use of a ceramic envelope is perhaps the outstanding feature of the new design, the stacked structure permits the alternative use of a glass envelope, where this may be preferable for some reason. Generally, the ceramic envelope is employed for severe environmental conditions. In the stacked assembly the complete mount is assembled on two small pins. A ceramic spacer is placed upon a base plate; the spacer is followed by a grid, another ceramic spacer, a cathode, a ceramic spacer, and so on, until the stack is completed. Finally, the small pins are riveted, thus holding the stack permanently together.

● *SLAG-GAS SHIELDED WELDING PROCESS*

The introduction of a new type of slag-gas shielded welding process has just been announced. This is a manually applied, semi-automatic welding process which makes it possible to deposit electrode metal at a rate of 10 to 40 and more pounds per hour. A flux is contained within the cavity of the electrode, which is of tubular construction. As the metal part of the electrode is melted by the heat of the arc and transferred through the arc to become part of the weld metal, the flux core also melts and is transferred through the arc to become the refining and shielding blanket of slag. Both the metallic part of the electrode and the flux transfer through the arc in a highly ionised state. While in this finely divided form, the flux, as well as the metal part of the electrode, would become highly oxidised unless shielded from the surrounding air. In order to prevent oxidation of the electrode materials while transferring through the arc, a separate gas, not a product of the flux, is used for shielding the arc column. It is pointed out that, without the new semi-automatic welding machine and the new arc welding torch, which were specially developed, the new high-speed welding process would not be possible. In the new torch, the welding current, the arc column shielding gas, the cooling water, and the welding electrode all pass through the handle of the torch. Furthermore, both the reel for holding the coiled electrode and the electrode feeding mechanism are fairly rigidly attached to the handle of the arc-welding torch. This feature permits the use of large-diameter electrodes.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

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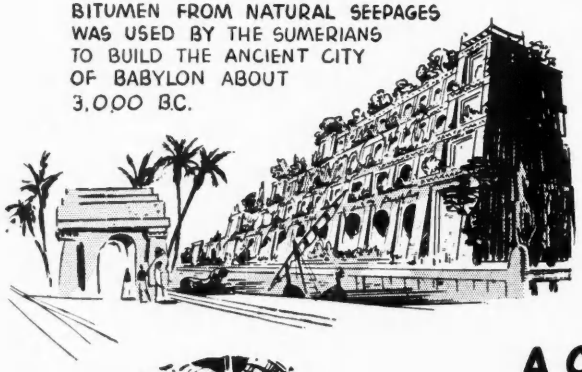

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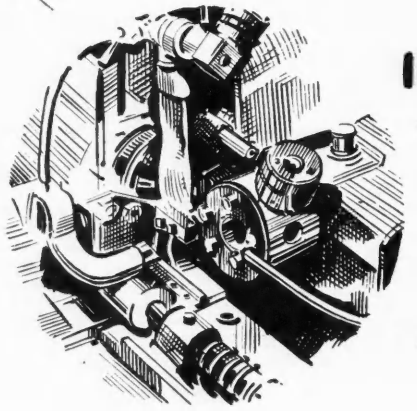

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